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THESIS

EXTENSIBLE 3D (X3D) GRAPHICS FOR VISUALIZING MARINE MAMMAL REACTION TO UNDERWATER SOUND ON THE SOUTHERN CALIFORNIA ASW RANGE (SOAR)

by

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June 2007

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VISUALIZING MARINE MAMMAL REACTION TO
UNDERWATER SOUND ON THE
SOUTHERN CALIFORNIA ASW RANGE (SOAR)

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ACRONYMS AND ABBREVIATIONS

ATOC   Acoustic Thermometry of Ocean Climate

AUTEC   Atlantic Undersea Test and Evaluation Center

AUV   Autonomous Underwater Vehicle

CINCPACFLT   Commander-in-Chief, Naval Forces, Pacific

dB   decibels

EMATT   Expendable Mobile Anti-Submarine Warfare Training Target

ESME   Effects of Sound on the Marine Environment

FM   Frequency Modulated

FOUO   For Official Use Only

GMT   Greenwich Mean Time

GPS   Global Positioning System

HARP   High-frequency Acoustic Recording Package

ISO   International Standards Organization

IUCN   Species Survival Commission of the World Conservation Union

IWC   International Whaling Commission

MMS   Mineral Management Service

MOVES   Modeling, Virtual Environments, and Simulation

MRSA   Multiplexed Range Sensor Array

MTU   Multiplexed Transmission Unit

M3R   Marine Mammal Monitoring

NAN   Not A Number

NASNI	Naval Air Station, North Island
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NPS	Naval Postgraduate School
NUWC	Naval Undersea Warfare Center
ONR	Office of Naval Research
OPAREA	Operating Area
PDT	Pacific Daylight Savings Time
REMUS	Remote Environmental Monitoring Units
RHIB	Rigid Hull Inflatable Boat
RIMPAC	Rim of the Pacific Exercise
SAVAGE	Scenario Authoring and Visualization for Advanced Graphical Environments
SCI	San Clemente Island
SCORE	Southern California Offshore Range
SOAR	Southern California Anti-Submarine Warfare Range
SOCAL	Southern California
TID	Target Identification
TDOA	Time Delay of Arrival
TOTO	Tongue of the Ocean
VRML	Virtual Reality Modeling Language
WHOI	Woods Hole Oceanographic Institution

XML   Extensible Markup Language

X3D   Extensible 3D Graphics

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I.   INTRODUCTION

A.   PROBLEM STATEMENT

The U.S. Navy's use of sonar is essential for national defense and as a consequence, training with sonar under realistic battle conditions is important. The Navy is working hard to understand the effects of these sonars on marine mammals. The Chief of Naval Operations Environmental Readiness Division (CNO (N45)) is sponsoring applied research to mitigate the impacts of Navy sonar use on marine mammals, while the Office of Naval Research (ONR) focuses on basic research issues to include the development of predictive models of marine mammal reaction to operational sonar. There is clearly a need for a system which visualizes actual marine mammal reaction during Navy exercises.

The primary goal of this thesis is to develop a tool for visualizing Anti-Submarine Warfare (ASW) exercises and marine mammal behavior on the Southern California ASW Range (SOAR). SOAR, which is part of the larger Southern California Offshore Range (SCORE), consists of 88 underwater hydrophones blanketing the ocean bottom off the western coast of San Clemente Island (SCI). In this thesis, Extensible 3D (X3D) Graphics is used to model tracks of acoustic sources, such as the Expendable Mobile ASW Training Target (EMATT). In addition, X3D recreates a test conducted 10-21 August 2006, where two research boats were present for the Marine Mammal Species Verification Test with Surface Observers, using on-range acoustic tracking of marine mammals and Global Positioning System (GPS) tracking of the boats. The result is a compilation of geographically-referenced and time synchronized visual scenes recreating marine mammal locations, based on vocalizations, allowing the X3D user to study marine mammal behavioral reaction to sound in the water.

Potential future work includes extending this model to marine mammal activity and reaction during on-range naval exercises, providing baseline data analyses that may be useful in better understanding marine mammal vulnerabilities, preparing environmental impact statements, and ensuring Navy compliance with the Marine Mammal Protection act of 1972.

B.   OVERVIEW OF THE PROBLEM

Reports of odd behavior, beach stranding, and deaths of marine mammals during Navy sonar use have been documented for several years. In March 2000, sixteen nearly simultaneous groundings of whales, eight of which were beaked whales, occurred along a 100-kilometer arc in the Bahamas. The Navy admitted that its sonar was "highly likely" the cause of these deaths (Malakow, 2001). Since the 1970s, there have been at least three reports of unusual strandings of beaked whales in close proximity to military exercises (2001). Incidents of naval sonar suspected of harming marine mammals includes exercises in Puerto Rico in 2002, 2000, and 1998; the Virgin Islands in 1999; Portugal's Madeira Islands in 2000; the Canary Islands in 2002; Greece in 1996; and the Gulf of Alaska in 2004 (McClure, 2006).

The military is not the only source of sound in the water believed to impact marine mammals. In the 1970s, seismic surveys, which use pulses of reflected sound to map oil and gas deposits, were disturbing ringed seals and bowhead whales in Alaska (Malakov, 2001). Preliminary studies by the National Oceanic and Atmospheric Administration (NOAA), using passive hydrophone arrays along the mid-Atlantic ridge to listen for underwater earthquakes and volcanoes, have found that a single oil exploration ship with its pressurized air-gun arrays "can sonify the entire North Atlantic" (2001). In the early 1990s, marine biologists opposed the Acoustic Thermometry of Ocean Climate (ATOC) project's use of seabed transmitters off the coast of California and Hawaii to produce low-frequency pulses that measured global ocean temperatures, claiming it disturbed the mating calls of humpback whales in the area (2001). Commercial shipping is also a major source of background noise in the world's oceans; at low frequencies between 5 and 500 Hz, the sound produced by these vessels is the same

as low sonic (<1000 Hz) and infrasonic (<20 Hz) calls of blue, fin, and sei whales (Mazzuca, 2001). Scientists are concerned that the increase in ambient noise is "masking" the communication of whales (Jasny and Reynolds, 1999). Thus, it comes as no surprise that a July 2004 report by the Scientific Committee of International Whaling Commission (IWC) declared that there is "compelling evidence" that noise pollution is a serious threat to marine mammals and a cause for "serious concern" (International Whaling Commission, 2004).

C. MOTIVATION

All parties involved in these issues share a mutual concern for the well-being of marine life. Unfortunately, a variety of factors may be contributing causes to these problems. Collection of accurate data is rare and correlation of causes and effects is typically qualitative and anecdotal, while Navy needs for training and operational use of sonar are quite real and critical to national defense. To reconcile these competing issues, CNO (N45) is seeking a scientific basis for decision making, based upon proper measurement and analysis of non-injurious effects.

Currently, there are no existing systems that use real data to track both whales and ships simultaneously. In a November 2006 email response from Bob Gisiner at the Marine Mammal Commission,

> Several models of animal interaction with sound fields have been created and are most frequently used for risk analyses in environmental risk predictions for activity planning and preparation of Environmental Assessments, Environmental Impact Statements, and similar documents.
>
> To my knowledge there have been few, if any, opportunities to test such models against real world data, so it would be difficult to say how successful any of them are in capturing actual exposures, and responses to exposures. We really know very little about how animals react to manmade sound, or to other sources.

The primary goal of this thesis is to develop a modeling and visualization tool for mobile acoustic sources that can be used as a baseline evaluation of marine mammal activity/reaction during exercises on the Southern California Anti-Submarine Warfare

Range (SOAR). By modeling the acoustic tracking of marine mammals during Navy exercises, this will provide high quality data and support the N45 mitigation procedures that may result in appropriately designed exercises for essential training, while reducing or eliminating negative impacts on marine life.

D. OBJECTIVES

Extensible 3D (X3D) Graphics, a web-based visualization tool, is used in this thesis for creating a scene of the San Clemente Island region. However, the authoring tool, Wings3D, and commercial player, Flux Studio, are also used in creating models, such as the hydrophones and whales. In addition, existing models in the online Savage archive, maintained by the MOVES Institute at the Naval Postgraduate School, are referenced in this thesis. Real data, including bathymetry and whale/ship tracking, are preprocessed first in MATLAB®, a software package for engineers, and Microsoft Excel®, before being incorporated into X3D models. SOAR, near San Clemente Island, is the focus of this thesis, and the objective is to create repeatable methodology for generating a visual display of real data.

E. THESIS ORGANIZATION

Chapter II reviews background information and technologies, as well as related work used during this research effort. Chapter III describes the creation of the bathymetry and hydrophone baseline of the authoring scene. Chapter IV introduces modeling in Wings3D and the use of the Savage archive. Chapter V outlines the process of animating real data in the scene. Chapter VI displays the overall scene. Chapter VII discusses problems faced along the way. Chapter VIII provides conclusions and recommendations for future work. The appendices provide MATLAB® functions, Excel® files, Savage model archives, selected JPEG files and X3D scenes from hourly whale tracking files, and news articles concerning the U.S. Navy's response to public concern for marine life.

II. BACKGROUND AND RELATED WORK

A. INTRODUCTION

This chapter provides background information on San Clemente Island and the Southern California Anti-Submarine Warfare Range. The M3R system used for collecting whale or marine mammal detection data is described, as well as systems used by other scientific groups. The dangers that face marine mammals are addressed, with a focus on anthropogenic sound. In addition, the efforts being made by different organizations to mitigate these issues are presented. This thesis seeks to build upon existing knowledge and work by using Extensible 3D (X3D) Graphics, Wings3D, Flux Studio, Savage, Savage Defense, X3D Earth, AUV Workbench, Global Mapper, and Rez. The following sections are intended to provide the reader with a basic knowledge of these sources. References are included for further research in each topic.

B. SAN CLEMENTE ISLAND (SCI) TEST SITE

SCI is located off the coast of southern California. Approximately 68 nautical miles west of San Diego, it is the southernmost of the eight California Channel Islands. SCI is 22 miles long by 4 miles wide, and its greatest height is approximately 1500 feet. Since 1934, the island has been owned by the Navy and operated by a succession of different naval commands. Today the Commander-in-Chief, Naval Forces, Pacific (CINCPACFLT) is the major claimant for the island, and Naval Air Station, North Island (NASNI) is responsible for its administration.

Off the western coast of SCI is the Southern California Anti-Submarine Warfare Range. Part of the Southern California Offshore Range (SCORE), SOAR is a training range where 88 in-water hydrophones are distributed over the contours of San Nicholas Basin between SCI and Tanner Bank. Maximum extreme depths on range vary from 1800 meters in the northwest to 800 meters in the southeast. Marine life is abundant, and approximately 480 species of marine fish and more than 5000 species of marine invertebrates inhabit the area (Geo-Marine, Inc., 2005). In addition, 45 marine mammal

species have been confirmed: 35 cetacean (whales, dolphins, porpoises), nine pinniped (seals, sea lions, and fur seals), and one fissiped (sea otter) species.

SCORE was commissioned in 1985. Originally covering 112 square miles, it was later enlarged to provide 670 square nautical miles of 3D underwater tracking capability (www.score.com). Military training exercises occur at SOAR to evaluate operational tactics, as well as test weapons, targets, and other vehicles. In the beginning, the acoustic tracking range consisted of twenty single hydrophone/cable system strings. In 1991, the Multiplexed Range Sensor Array (MRSA), an underwater acoustic signal detection and transmission system, was built to include eight in-water sensor strings (Science Applications International Corporation MariPro Operations, 1991). In Figure 1, the strings are labeled B-I.
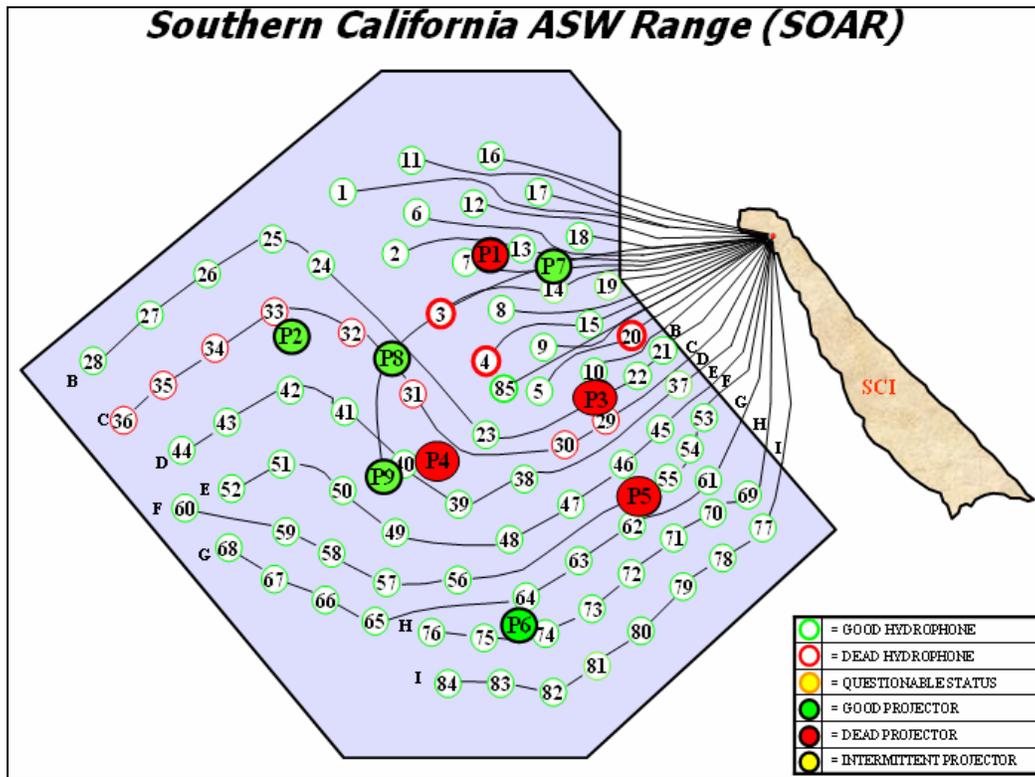
Figure 1. **Southern California Offshore Anti-Submarine Warfare Range showing approximate layout of 88 in-water hydrophones off the western coast of San Clemente Island (from www.score.net).**

Each sensor string consists of eight hydrophone sensor nodes called Multiplexed Transmission Units (MTUs). The purpose of each MTU is to receive underwater acoustic signals over the 8-35 kHz band, and transmit these signals on a cable to a shore station for processing. The design of a standard MTU can be seen in Figure 2.
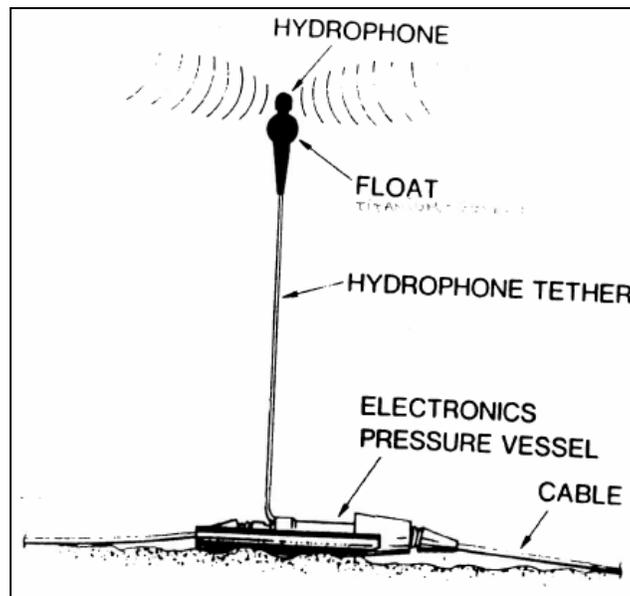
Figure 2.   Diagram of in-water hydrophone located in SOAR (from Science Applications International Corporation MariPro Operations, 1991).

C.   SYSTEMS FOR COLLECTING DATA

1.   Marine Mammal Monitoring (M3R)

In addition to the SCORE hydrophones' use for tracking targets in support of military ASW training, they also serve the scientific community for the Marine Mammal Monitoring on Navy Ranges (M3R) project. Funded by the Office of Naval Research (ONR), M3R utilizes pre-existing Navy undersea ranges to automatically collect data using passive acoustics. Applications include estimating marine mammal abundance, assessing bio-acoustic behavioral baseline, and evaluating the impacts of anthropogenic noise by comparison to those baselines. The Principal Investigator of M3R is Dave Moretti from the Naval Undersea Warfare Center (NUWC) Division in Newport, RI.

The Marine Mammal Monitoring program began in April 2002 at the Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) off the shore of Andos Island, Bahamas. Located 177 nm from the south Florida coast in the Tongue of the Ocean (TOTO) basin, the range consists of 12 original broadband hydrophones, plus an additional 68 that AUTEC installed. The reason why the M3R project began at AUTEC was because of its position in relation to the TOTO - a deep-water canyon that provides an isolated, quiet environment. Depths range from over 1200 m at the canyon center to 5 m near the barrier reef. Marine mammals that have been recorded in the area include the sperm whale (*Physeter macrocephalus*), minke whale (*Balaenoptera acutorostrata*), short-finned pilot whale (*Globicephala macrorhynicus*), and the bottlenose dolphin *(Tursiops truncates)*. By discriminating call types and determining basic call characteristics for species, scientists are increasing the library of knowledge in understanding how marine mammals communicate.

2. High-frequency Acoustic Recording Packages (HARPs)

Besides NUWC's involvement in marine mammal monitoring in the AUTEC and San Clemente areas, Dr. John Hildebrand from the Scripps Institution of Oceanography at the University of California San Diego has been leading efforts using High-frequency Acoustic Recording Packages (HARPs). HARPs are tethered hydrophones above seafloor-mounted instrument frames that have been deployed to record baleen whale sounds for long periods of time, typically up to one year (Wiggins, 2003). Each consisting of a frame that contains buoyancy for recovery, ballast weights for deployment, and pressure cases for batteries/ballast release/data logger electronics, HARPs are necessary to obtain long-term recordings of baleen whales, primarily blue (*Balaenoptera musculus*) and fin (*Balaenoptera physalus*) whales, and to develop population and abundance estimates of the calling whales. These whales are on the endangered list, and little is known about them, especially the blue whale.

3. Autonomous Underwater Vehicles (AUVs)

Although not directly related to marine mammal studies near SCI, another form of detecting and tracking whales is being developed by the Woods Hole Oceanographic Institution (WHOI) in Massachusetts, as well as the Applied Physics Laboratory at the University of Washington. Autonomous Underwater Vehicles (AUVs) are now being used as passive acoustic recorders to study where marine mammals go and what they do over periods of weeks and months. The advantages are: a) These ocean gliders are unaffected by weather, b) can travel down to depths of 1000 m, c) operate silently, and d) travel among sites of interest rather than recording marine mammals at a single location. Future efforts in improving the AUVs include: extending the length of recording, developing a capability to report whale vocalizations to researchers on land rapidly and in real time, and monitoring higher frequency vocalizations of dolphins, sperm whales, and beaked whales.

D. ENDANGERED SPECIES

In 1994, the Species Survival Commission of the World Conservation Union (IUCN) released its Red Data Book, documenting conservation status of and threats to whales, dolphins, and porpoises, as well as principle threats facing cetaceans. "Seventy-four percent of the thirty-eight cetacean species for which sufficient data were available were either considered threatened (fourteen species) or would be so if current conservation measures were stopped (fourteen species)" (Mann et. al., 2000). The humpback and sperm whale are vulnerable, facing a high risk of extinction in the wild in the medium-term future. The fin, blue, sei, and northern right whale are endangered, facing a very high risk of extinction in the wild in the near future. In addition to anthropogenic noise, other threats facing cetaceans include, but are not limited to, effects of past exploitation, fishing by-catch, habitat degradation, heavy metals, and global warming.

E. A FOCUS ON ANTHROPOGENIC NOISE

The focus of this thesis is to develop a tool for helping to understand the noise impact on marine mammals and their behavioral reaction. There are recorded accounts where whales deliberately change course when noise is detected. For instance, during the Acoustic Thermometry of the Ocean Climate (ATOC) Marine Mammal Research Program, low-frequency (75 Hz) sound broadcasts temporarily affected the surface behaviors of Hawaiian humpback whales (Frankel and Clark, 1998, 2000). In another example, beluga whales and narwals in the Canadian High Arctic intentionally avoided icebreakers approaching at ranges of 40-60 km. It took up to 48 hours after the ship passed before these belugas resumed normal activities (Mann et. al., 2000). A third instance of whale reaction to noise was a mass stranding of Cuvier's beaked whales (*Ziphius Cavirostris*) in Greece, which probably resulted from military sonar being tested in the area (Frantzis, 1998). Cuvier whales typically dive deeper and longer than other marine mammals (Johnson et. al., 2005). It is conceivable that when exposed to loud sounds, they may become frightened and quickly rise to the surface, thereby suffering from symptoms consistent with decompression sickness (Jepson, 2004).

F. REGULATORY AND GOVERNMENT AGENCY EFFORTS

Many efforts are being made by government agencies to reduce noise impact on marine mammals. Researchers at the National Oceanic and Atmospheric Administration (NOAA) are working with the shipping industry to build quieter ships. The Interior Department's Mineral Management Service (MMS) has a research program for understanding how the spread of oil drilling in the deep waters of the Gulf of Mexico affects sperm and other whales. The Chief of Naval Operations Environmental Readiness Division (CNO (N45)) funds many marine mammal studies, including the Marine Mammal Verification Test with Surface Observers conducted by the Naval Undersea Warfare Center (NUWC) and Cascadia Research. N45 goals include: a) understanding marine mammal demographics, b) determining certain thresholds and usefulness of mitigation methods, and c) using passive acoustic monitoring, particularly on Navy undersea ranges, to obtain information about marine mammal normal/abnormal

behavior. The Office of Naval Research (ONR) has sponsored three-dimensional computer models for predicting how some species of whales will react to sounds, one being the Effects of Sound on the Marine Environment (ESME) model (Gisiner et. al., 2006). Dr. Peter Tyack at the Woods Hole Oceanographic Institution has made many discoveries about whale behavior. For instance, when exposed to sonar, male humpback whales in the Hawaiian breeding grounds sang, on average, 29% longer, but returned to normal solos shortly after the signals ended (Fristrup et al., 2003).

Focusing on the Southern California Operating Area, the California Coastal Commission continues to make efforts to address marine mammal and sea turtle monitoring, minimization, and mitigation measures related to mid-frequency sonar. The Commission believes that Navy exercises with the potential to disturb marine mammals include "ship movement, inert mine drops, underwater detonations, and, outside the coastal zone, mid-frequency sonar, missile launches, and amphibious landings" (California Coastal Commission, 2007). A number of policies have been proposed in order to protect marine mammals, one being the reduction of a behavioral harassment "threshold" from 186 dB to 154 dB (2007). For a complete list of proposed conditions, refer to "CD-086-06, Navy Training Exercises Southern California," http://documents.coastal.ca.gov/reports/2007/1/W10b-1-2007.pdf.

G.   THE EFFORTS OF THIS THESIS

It is important for organizations, including the Navy, to have sound scientific evidence to understand what type of reaction, if any, whales have to noises like sonar operations, and then use this knowledge in order to mitigate any negative impact. Extensible 3D (X3D) Graphics is a web-based visualization tool for simultaneously incorporating marine mammal tracking during ship movement/sonar exercises, supporting CNO (N45) goals and allowing scientists to study and measure its effectiveness.

1.   Extensible 3D (X3D) Graphics

X3D Graphics is a computer graphics standard, used primarily for this thesis. It uses the open standards Extensible Markup Language (XML), allowing for real-time communication of 3D data across all applications. X3D has replaced the 1997 version of the Virtual Reality Modeling Language (VRML), which was International Standards Organization (ISO)-bound. X3D is preferred over VRML for several reasons: it is VRML compatible, operates predictably between different browsers/players, is more feature-rich, its binary format offers encryption (i.e., security) and compression (i.e., speed), and allows the use of the Xj3D application as a developer resource (Bouras et al., 2005). A more detailed explanation of X3D Graphics is provided in Extensible 3D (X3D) Graphics for Web Authors (Brutzman & Daly, 2006).

2.   X3D Browsers and Authoring Tools

In addition to X3D and its browsers, the following authoring tools were used to augment this thesis: Wings3D, Flux Studio, Savage, Savage Defense, AUV Workbench, Global Mapper, and Rez.

a.   *Wings3D Authoring Tool*

Wings3D is an open-source authoring tool, allowing users to create complex 3D models with an intuitive interface. However, Wings creates objects using wire frame meshes, which must be modified before incorporation into an X3D scene. For more information about Wings3D, see http://www.wings3d.com.

b.   *Flux Studio Scene Authoring Tools*

Flux Studio is an X3D commercial player, capable of fully integrating the entire X3D scene graph. It allows the import and export of multiple file formats, and was used in this thesis for making visual adjustments of models created in Wings3D. Additional information about Flux is available at http://www.mediamachines.com/.

c.   *SAVAGE*

The Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) is an open-source online archive, containing over one thousand 3D models. The site is maintained and updated by the Modeling, Virtual Environments, and Simulation (MOVES) department at the Naval Postgraduate School (NPS). Many pre-existing 3D models were modified and referenced in this thesis to create the resulting virtual scenes. These include the Rigid Hull Inflatable Boat (RHIB), acoustic transmission prototypes, Remote Environmental Monitoring Units (REMUS), WaypointInterpolator, and DVD Controller. See https://savage.nps.edu/Savage for a complete list of models.

d.   *SAVAGE Defense*

The Savage Defense archive is similar to Savage, but the models contained in it are restricted access and considered For Official Use Only (FOUO). Most scene components for this thesis were placed in Savage Defense, with the exception of the whale and RHIB. The site https://savagedefense.nps.navy.mil/SavageDefense provides a catalog and archive of models.

e.   *AUV Workbench*

The NPS Autonomous Underwater Vehicles (AUV) Workbench supports physics-based AUV modeling and visualization of vehicle behavior and sensors in all mission phases. Graphical mission generation and data handling includes integrated sonar visualization capabilities. The AUV Workbench auto installer is publicly available at http://online.ern.nps.edu/AUV/workbench/install.htm.

f.   *X3D Earth*

The X3D Earth Project is an open-source, standards-based 3D infrastructure for visualizing real-world objects in a geo-spatial context. The goal of this visualization framework is to model bathymetry and topography across the entire globe. For the latest updates on X3D Earth, refer to www.web3d.org/x3d-earth.

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g.   *Global Mapper and Rez*

Global Mapper is a comprehensive software package capable of displaying raster, elevation, and vector datasets. It was used in this thesis for reading and displaying bathymetry and topography data directly from the www.ngdc.noaa.gov website, using the ASCII raster format.

Rez is an open source framework and tools for modeling large 3D terrains over the web. Rez was used in this thesis for modeling higher resolution (three-second) bathymetry and topography data of San Clemente Island and SOAR. Instructions for downloading Rez can be found at http://planet-earth.org/Rez/RezIndex.html.

H.   SUMMARY

This chapter provides an overview of the technologies and prior work used for completing this thesis. Descriptive features of San Clemente Island and the Southern California ASW Range are mentioned, as well M3R used for collecting marine mammal vocalizations. HARPs and AUVs are also discussed to provide the reader with knowledge of other systems used for scientific studies. The impacts facing marine mammals, specifically anthropogenic sound, have been an important focus of government agencies like NOAA, MMS, ONR, N45, WHOI, and CCC. This thesis models real data with X3D Graphics in order to visualize marine mammal behavioral reaction to sound at SOAR. In addition, the tools Wings3D, Flux Studio, Savage, Savage Defense, Global Mapper, and Rez are used.

III. CREATING BASELINE MODELS OF BATHYMETRY AND HYDROPHONES

A. INTRODUCTION

The standardized format and implementation of bathymetric and topographic data, hydrophone positions, and SOAR boundary data are discussed in this chapter. The process of acquiring data from the National Geophysical Data Center (NGDC) is described, as well as the implementation of such information into ElevationGrid of X3D Graphics. When ElevationGrid is not sufficient, the use of Global Mapper and Rez for higher resolution scenes are explained. The incorporation of hydrophones and SOAR boundary coordinates are the final touches in creating a baseline for this thesis.

B. OBTAINING BATHYMETRIC DATA FROM THE NATIONAL GEOPHYSICAL DATA CENTER

Combined bathymetry and topography data for San Clemente Island and SOAR are accessible to the public at the NGDC website (http://www.ngdc.noaa.gov), where a custom interface, "GEODAS Grid Translator - Design-a-Grid," allows the user to specify the coordinates, database, and output grid format for the downloaded data (Figure 3). Appendix B Part A represents a section of the downloaded 30-second NGDC data.
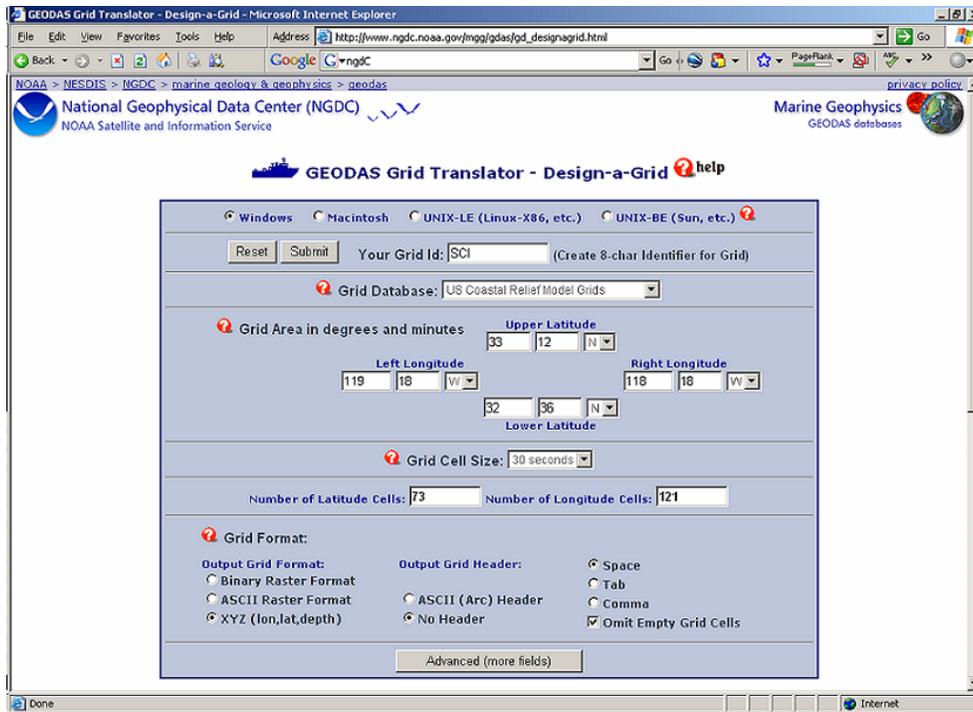
Figure 3. **Design-a-Grid site of www.ngdc.noaa.gov, used to download bathymetry and topography data of San Clemente Island and SOAR with 30-second and 3-second resolution.**

C. ELEVATIONGRID

ElevationGrid was used in this thesis rather than GeoElevationGrid for a few reasons. First, the format of the downloaded NGDC file was the same as the ElevationGrid, meaning the origin of the scene was the upper-left (northwest) corner of the grid. The grid was built west to east using only heights/depths (+/-Y), then incremented north to south with the completion of each row. The X3D Specifications for this standard can be found at: http://www.web3d.org/x3d/specifications.

Second, ElevationGrid was used because the browsers Cortona and Flux were able to render the scene, which was not the case for GeoElevationGrid. In addition, the area of San Clemente Island and the SCORE range was small enough that a distortion due to Earth's curvature did not greatly affect the modeled scene in X3D.

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1. Coordinates for Model

The following coordinates outlined the boundaries of the scene: 33.2º northern boundary, 32.6º southern boundary, -119.3º western boundary, and -118.3º eastern boundary. Because 30-second spacing was used, the grid was 73 x 121. X represented longitudes from west to east, and in the xDimension of ElevationGrid, 121 was entered. Z represented latitudes from north to south; in the zDimension 73 was entered. See Figure 3 for an illustration of the X3D coordinate system.
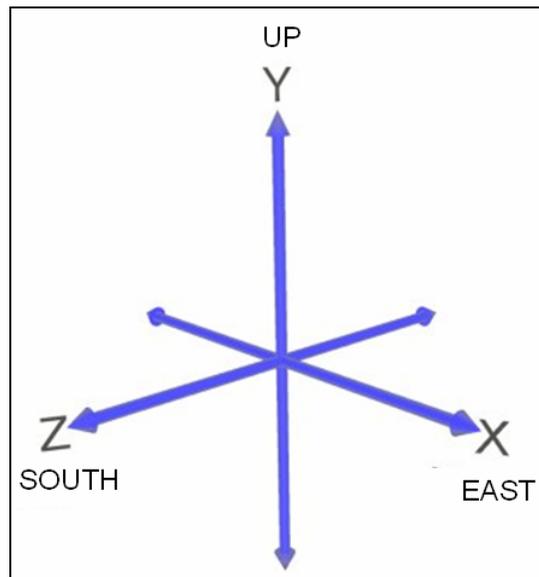
Figure 4. **XYZ coordinate system used in this thesis (from Brutzman & Daly, 2006).**

2. Spacing for Model

To calculate spacing, the MATLAB® Mapping Toolbox was used to convert latitude and longitude information into distances from the northwest reference point (Appendix A Part A). The shortest distances along the north and south boundaries of the area were calculated: 93044 m for the northern boundary and 93676 m for the southern boundary. This difference of 632 m was small enough compared to the overall lengths (less than 1%) that such a distortion was safely ignored. Using an average of the two sides (93360 m) and dividing by 120 (the number of increments between 121 points), xSpacing (north/south) was set at 778 m. So, the more positive the X value, the farther

right (or east) an object was. The west and east boundaries were both 66717 m. With 73 latitudes, dividing by 72 increments put zSpacing (west/east) at 927 m (rounded to the nearest meter). So, the more positive the Z value, the further south an object was. As a result, every coordinate in the scene had positive X and Z values, and the maximum values for X were 93360 m and for Z 66717 m.

D.   GLOBAL MAPPER AND REZ FOR HIGHER RESOLUTION BATHYMETRY

The three-second bathymetry and topography data of San Clemente Island and SOAR were downloaded in the ASCII raster format on the NGDC website and saved as a file named NGDC_7186.asc. In Global Mapper, this file was opened, and the screen "Select Projection for NGDC_7186.ASC" appeared. The settings demonstrated in Figure 5 were chosen, and a visual of the data was displayed (Figure 6). This Raster and Elevation Data were then exported as VRML. The "VRML World File Export Options" (Figure 7) came up, and the default X-axis and Y-axis of .00083 were used for the three-second data. Note, the box for 'Generate Compressed WRZ File' was unchecked. The VRML file was then saved as ngdc.wrl. Once the texture image was exported, the settings for "JPG Export Options," as seen in Figure 8, were selected. This concluded the Global Mapper process.
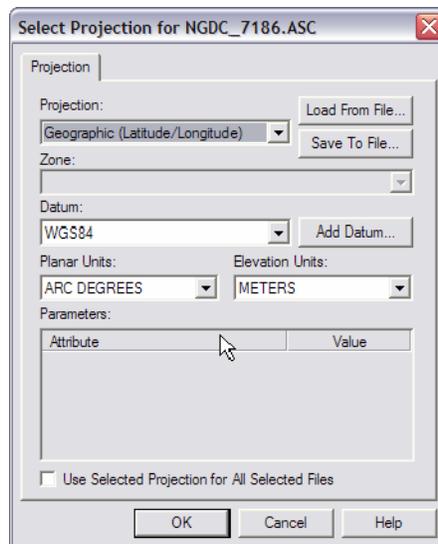
Figure 5.   Global Mapper Setting Projection for NGDC_7186.ASC file.
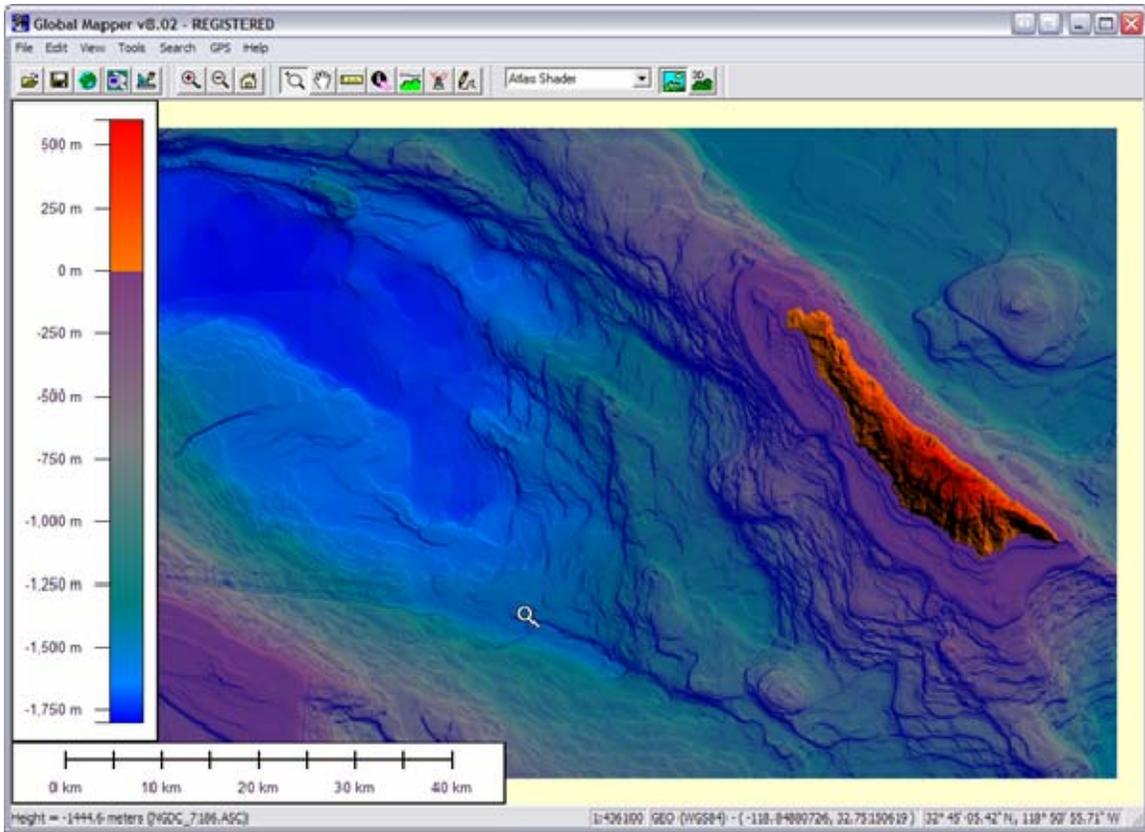
Figure 6. **Global Mapper display of NGDC raster and elevation data.**
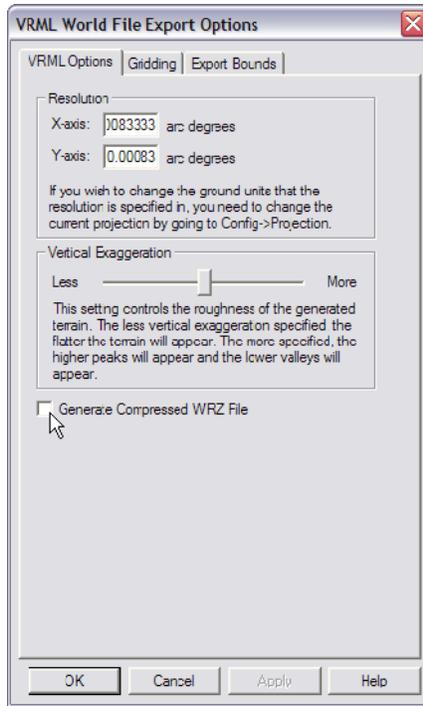
Figure 7. **Global Mapper VRML World File Export Options with default settings.**
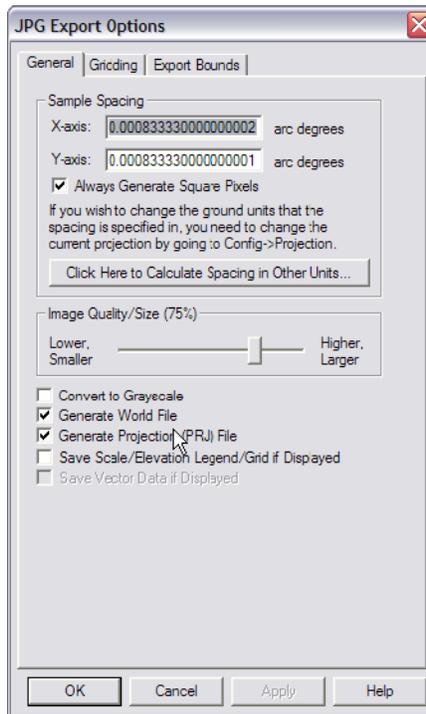
Figure 8. **Global Mapper JPG Export Options with default settings.**

Next, Rez was used, and the files needed were Rez.jar (execution binary), testX3D.bat (batch command), testX3D.txt (configuration file), and ngdc.wrl (input elevation data). First, testX3D.bat was run, and in "Simple Rez GUI test (Figure 9)," all settings were left at default. When finished running, the output of Rez was composed of 0-10 levels of detail (Figure 10).
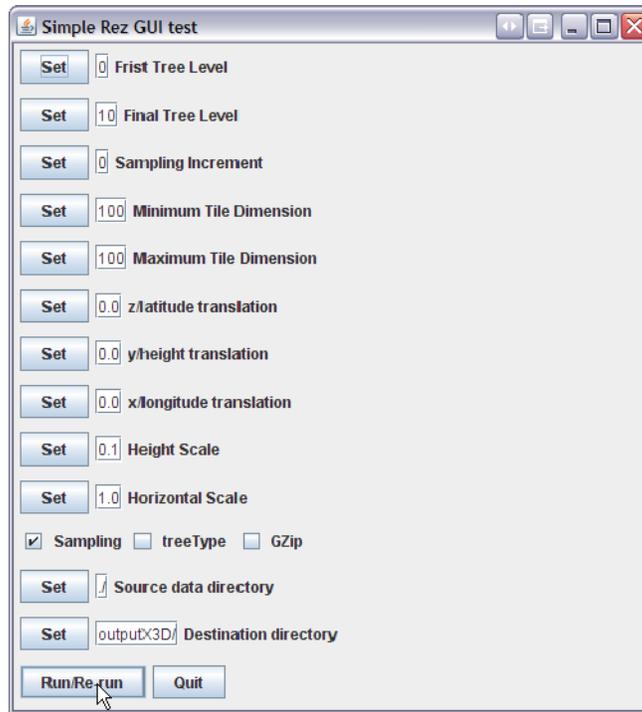
Figure 9. **Simple Rez GUI test with default settings.**
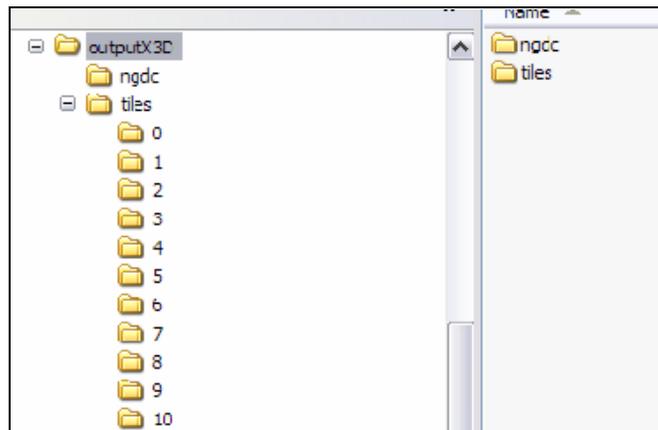
Figure 10. **Rez output of 0-10 levels of bathymetry and topography detail.**

A Rez Image Slicer was used as the last step in preprocessing the bathymetry and topography data before rendering it in a browser. The files used were slice.jar (execution binary), ImageSlice.bat (batch command), and ngdc.jgp (input image). Running ImageSlice.bat, the output was a file of "images" containing 0-10 levels of detail (Figure 11). This "image" folder was moved to the "outputX3D," and the final X3D file was "ouputX3D\ngdc\Display.x3d" (Figure 12).

For the purpose of this thesis, the lowest 0 level of detail for San Clemente Island bathymetry was incorporated into the Savage Defense X3D model archive.
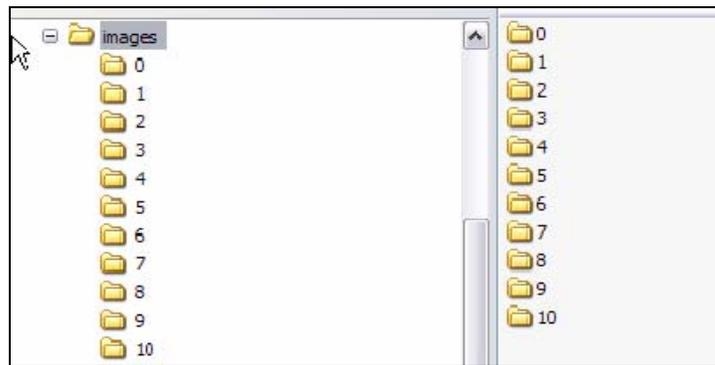
Figure 11.   Rez output of 0-10 levels of image texture detail.
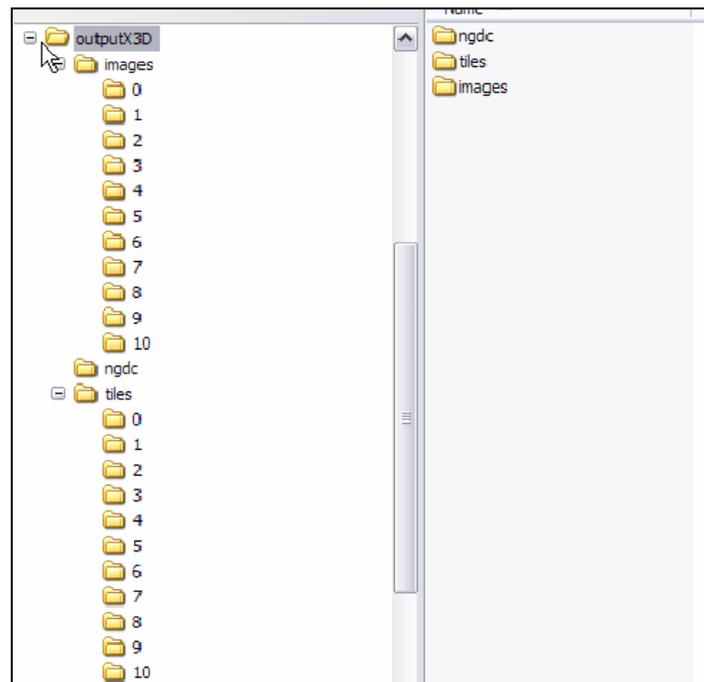
Figure 12.   Final Rez output X3D file, "output\ngdc\Display.x3d."

Loading the outputX3D file into an X3D browser (i.e., Flux), the viewpoint was changed by right-clicking and selecting any one of the Viewpoints 1-8. Then, the "visibilityLimit" was increased in order to avoid clipping of the rendered model. This was accomplished by opening the scene in X3D-Edit graph editor.

When the above steps were completed, the final product was rendered in an X3D browser (Figure 13).
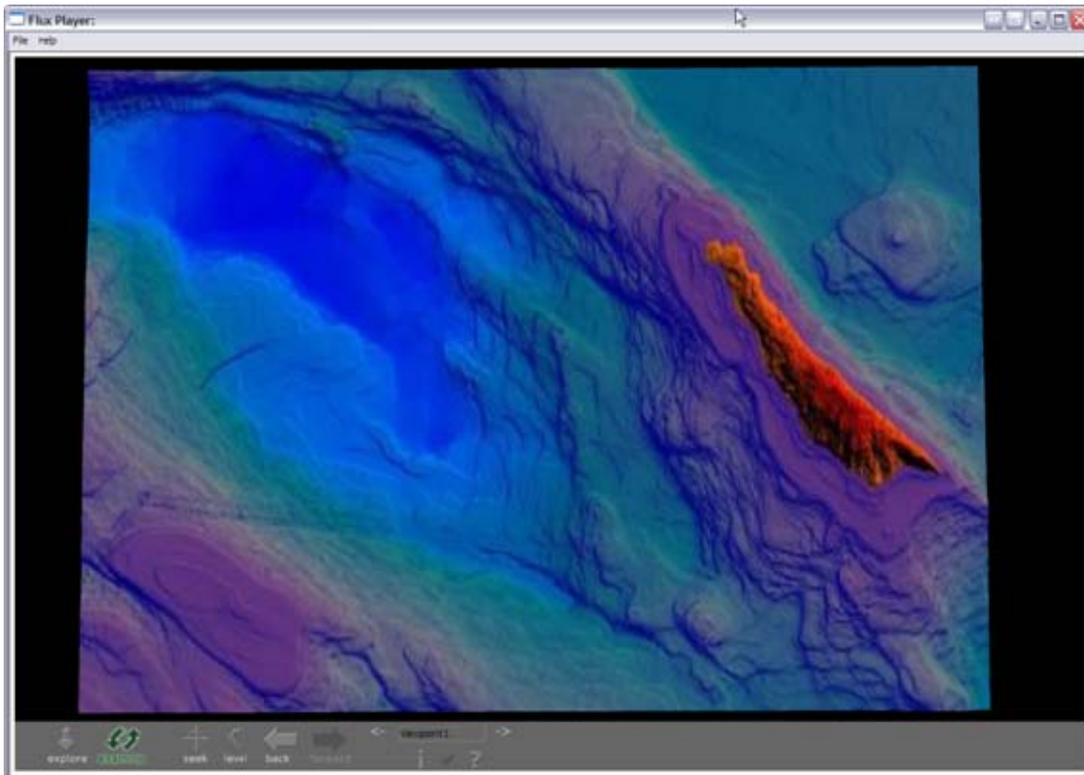
Figure 13.   Final bathymetry and topography data displayed in an X3D browser.

E.   HYDROPHONE POSITIONS

The positions of the 88 hydrophones in the SCORE range were originally given in decimal-degree format for the latitudes and longitudes, while the depths were given in feet. Once the depths were converted into meters, an Excel® file with three worksheets was created, along with a MATLAB® routine for reading the hydrophone Excel® file (Appendix A Part B). Editing was required to transform the data on the original

worksheet into a number format on the second worksheet. The third worksheet contained the final format of latitude, longitude, and depth data used for modeling the hydrophone locations.

F.   SOAR BOUNDARIES

The SOAR boundary limits were outlined by using an IndexLineSet. The latitude and longitude coordinates were: 33.1345º -118.92517º, 33.1345º -118.76733º, 33.09367º -118.72617º, 32.9815º -118.72533º, 32.78933º -118.53633º, 32.61533º -118.74833º, 32.61533º -118.94983º, and 32.905º -119.22483º (www.scisland.org). These coordinates were converted into X and Z distances in meters with respect to the northwest corner (Figure 14) and can be viewed at

https://savagedefense.nps.navy.mil/SavageDefense/Locations/SanClementeIslandCalifornia/SCISCOREBoundaries.x3d.
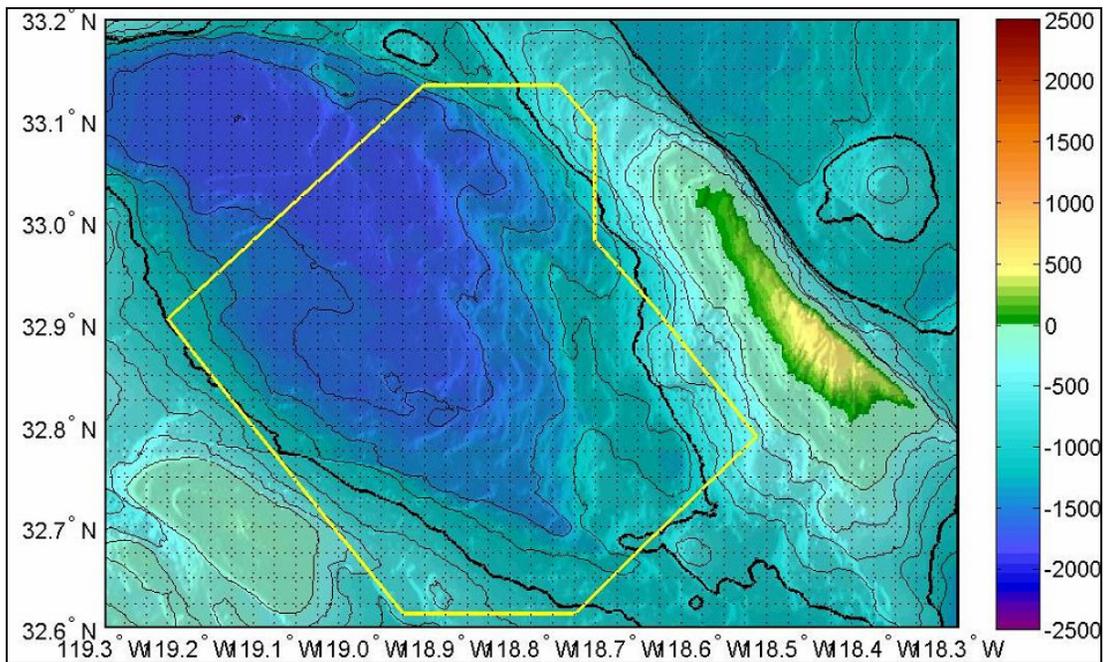
Figure 14.   Coordinates of Southern Offshore Anti-Submarine Warfare Range boundary limits off the western coast of San Clemente Island.

G.   SUMMARY

This chapter discusses the process of obtaining bathymetric and topographic data of San Clemente Island and surrounding waters from the NGDC website and incorporating them into ElevationGrid of X3D. When three-second resolution data can not be rendered with X3D browsers, Global Mapper and Rez provide satisfactory models that display the highest resolution of NGDC bathymetry and topography. Models for hydrophone positions and the SOAR boundary are plotted and provided.

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IV. X3D MODELS FOR THE SAVAGE AND SAVAGE DEFENSE ARCHIVES

A. INTRODUCTION

In this chapter, models used in this thesis from the Savage and Savage Defense archives are described, as well as models created by the author. They include the Rigid Hull Inflatable Boat, Expendable Mobile Anti-Submarine Warfare Training Target, EMATT Ping Sequence, Bathymetric and Topographic Coloring, Waypoint Interpolator, DVD Controller, Hydrophone, and Whale.

B. RIGID HULL INFLATABLE BOAT (RHIB)

The RHIB from the Savage archive was incorporated into this thesis (https://savage.nps.edu/Savage/ShipsMilitary/RHIB-UnitedStates/Rhib.x3d) and is illustrated in Figure 15.
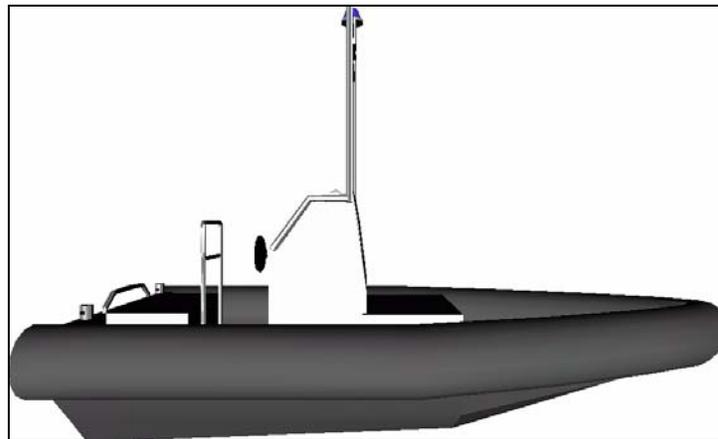
Figure 15.   Rigid Hull Inflatable Boat model.

C. EXPENDABLE MOBILE ANTI-SUBMARINE WARFARE TRAINING TARGET (EMATT)

The MK 39 EMATT is a "small, dynamic submarine-like target equipped with acoustic and non-acoustic signatures" that can be deployed from aircraft or surface ships (http://www.sippican.com/contentmgr/showdetails.php/id/345).

An EMATT model was created in X3D (https://savagedefense.nps.navy.mil/SavageDefense/Robots/UnmannedUnderwaterVehicles/EMATT.x3d) as an adaptation of the Remote Environmental Monitoring Units (REMUS) in the Savage archive because of its similar shape. Figure 16 is a photograph of an EMATT, provided by Sippican.

Figure 16.   Expendable Mobile Anti-Submarine Warfare Training Target model (from www.sippican.com).

D. EMATT PING SEQUENCE

Three modified EMATTs were used in an experiment conducted by NPS and programmed to project three transmitted signal types: six seconds of tones (900 Hz or 400 Hz), six seconds of frequency modulated (FM) sweeps, and six seconds of an m-sequence coded signal. This 18-second broadcast every minute was followed by 42 seconds of silence.

To illustrate when an EMATT transmits sound, EmattPingSequenceTest, EmattPingSequencePrototype, and EmattPingSequenceExample scenes were created, based on the AcousticTransmissionCylinderExample in the Savage archive. Three slightly different shades of orange were used to visualize each signal type (Figure 17).
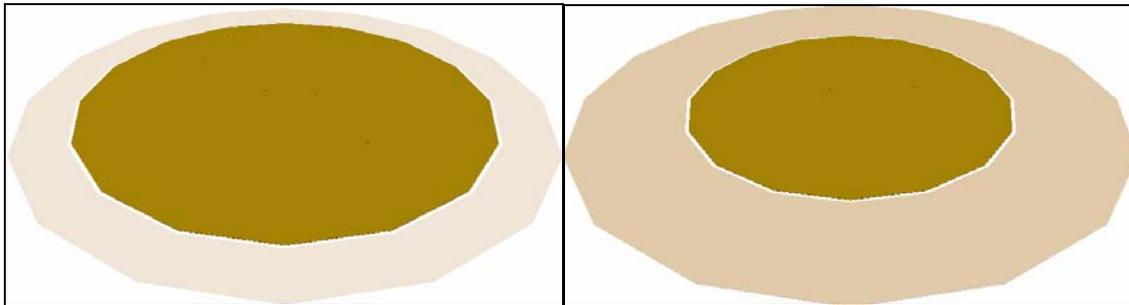
Figure 17.   EMATT ping sequence, consisting of three signals lasting six seconds each.

The EmattPingSequenceTest contained the ExternProtoDeclare from the AcousticTransmissionCylinderExample connecting its fields via three ROUTEs (from TouchSensor to TimeSensor, from TouchSensor to BooleanFilter, from BooleanFilter to TimeSensor). In addition, three ProtoInstances were added, labeled EMATTSoundCylinder1, EMATTSoundCylinder2, and EMATTSoundCylinder3. For each, a controlling BooleanSequencer (BS1, BS2, and BS3) and two ROUTEs were added. The ROUTEs connected from TimeSensor to BooleanSequencer, and from BooleanSequencer to its respective ProtoInstance. For example, in ProtoInstance EMATTSoundCylinder1, the first ROUTE connected TimeSensor to the BooleanSequencer labeled BS1, and the second ROUTE connected BS1 back to EMATTSoundCylinder1. A section of the script in

https://savagedefense.nps.navy.mil/SavageDefense/Robots/UnmannedUnderwaterVehicles/EmattPingSequenceTest.x3d can be viewed in Figure 18.

```
!-- MasterClock ROUTEs: [from SingleTransmissionTextTouch.touchTime to set_startTime ] [from EnabledTrueFilter.inputTrue to enabled ]
rom fraction_changed to BS1.set_fraction ] [from fraction_changed to BS2.set_fraction ] [from fraction_changed to BS3.set_fraction ] -->
TimeSensor DEF='MasterClock' cycleInterval='60' enabled='false' loop='true'/>
Transform DEF='DistantViewPoint' rotation='1 0 0 -0.7' translation='0 1000 1800'>

                <!-- SingleTransmissionTextTouch ROUTEs: [from touchTime to MasterClock.set_startTime ]
                [from isActive to EnabledTrueFilter.set_boolean ] -->
                <TouchSensor DEF='SingleTransmissionTextTouch' description='SingleTransmissionText'/>
                <ROUTE fromNode='SingleTransmissionTextTouch' fromField='touchTime' toNode='MasterClock' toField='set_startTime'/>
                <!-- EnabledTrueFilter ROUTEs: [from SingleTransmissionTextTouch.isActive to set_boolean ] [from inputTrue to MasterClock.enabled ]
                -->
                <BooleanFilter DEF='EnabledTrueFilter' containerField='children' inputTrue='' inputFalse='' inputNegate=''/>
                <ROUTE fromNode='SingleTransmissionTextTouch' fromField='isActive' toNode='EnabledTrueFilter' toField='set_boolean'/>
                <ROUTE fromNode='EnabledTrueFilter' fromField='inputTrue' toNode='MasterClock' toField='enabled'/>

<!-- EMATTSoundCylinder1 ROUTE: [from BS1.value_changed to startTransmission ] -->
<ProtoInstance name='AcousticTransmissionCylinder' DEF='EMATTSoundCylinder1' containerField='children'>
    <fieldValue name='defaultRange' value='1000'/>
    <fieldValue name='transmissionDuration' value='6'/>
    <fieldValue name='color' value='1 1 0.2'/>
</ProtoInstance>
<!-- BS1 ROUTEs: [from MasterClock.fraction_changed to set_fraction ] [from value_changed to EMATTSoundCylinder1.startTransmission ] -->
<BooleanSequencer DEF='BS1' key='0 0.1 0.2 0.3 1' keyValue='true false false false false' containerField='children'/>
<ROUTE fromNode='MasterClock' fromField='fraction_changed' toNode='BS1' toField='set_fraction'/>
<ROUTE fromNode='BS1' fromField='value_changed' toNode='EMATTSoundCylinder1' toField='startTransmission'/>
```

Figure 18.   EMATTPingSequenceTest script, displaying ProtoInstance EMATTSoundCylinder1 and connecting routes.

The second step was to make an EMATTPingSequencePrototype. Following the ExternProtoDeclare named 'AcousticTransmissionCylinder,' a ProtoDeclare named 'EmattPingSequence' was added to include a ProtoInterface and ProtoBody. This ProtoBody contained the timeSensor 'MasterClock' and the three ProtoInstances from before: 'EMATTSoundCylinder1,' 'EMATTSoundCylinder2,' and 'EMATTSoundCylinder3.' In addition, a ProtoInstance named 'EmattPingSequnce' (DEF= 'EmattPingInstance') was created to include a Transform node with a Billboard Text ("Three 6 second transmissions every minute"), BooleanFilter, and three ROUTEs. The ROUTEs associated with this ProtoInstance connected TouchSensor to ProtoInstance, TouchSensor to BooleanFilter, and BooleanFilter to ProtoInstance (Figure 19). See

https://savagedefense.nps.navy.mil/SavageDefense/Robots/UnmannedUnderwaterVehicles/EmattPingSequencePrototype.x3d for the complete script of the EmattPingSequencePrototype.

```
<!-- EmattPingInstance ROUTEs: [from SingleTransmissionTextTouch.touchTime to startTime] [from EnabledTrueFilter.inputTrue to enabled] -->
<ProtoInstance name='EmattPingSequence' DEF='EmattPingInstance' containerField='children'/>
<Transform DEF='DistantViewPoint' rotation='1 0 0 -0.7' translation='0 1000 1800'>

    <!-- SingleTransmissionTextTouch ROUTEs: [from touchTime to EmattPingInstance.startTime]
    [from isActive to EnabledTrueFilter.set_boolean] -->
    <TouchSensor DEF='SingleTransmissionTextTouch' description='SingleTransmissionText'/>
    <ROUTE fromNode='SingleTransmissionTextTouch' fromField='touchTime' toNode='EmattPingInstance' toField='startTime'/>
    <!-- EnabledTrueFilter ROUTEs: [from SingleTransmissionTextTouch.isActive to set_boolean]
    [from inputTrue to EmattPingInstance.enabled] -->
    <BooleanFilter DEF='EnabledTrueFilter' containerField='children' inputTrue='' inputFalse='' inputNegate=''/>
    <ROUTE fromNode='SingleTransmissionTextTouch' fromField='isActive' toNode='EnabledTrueFilter' toField='set_boolean'/>
    <ROUTE fromNode='EnabledTrueFilter' fromField='inputTrue' toNode='EmattPingInstance' toField='enabled'/>
```

Figure 19.   EMATTPingSequencePrototype script, displaying ProtoInstance 'EmattPingSequence' section.

Lastly, EMATTPingSequnceExample was created and placed in

https://savagedefense.nps.navy.mil/SavageDefense/Robots/UnmannedUnderwaterVehicl es/EmattPingSequenceExample.x3d.

Although the signal duration for each EMATT was the same, the start time for such a signal was different depending on what time the program was started. On 13 August 2004, three EMATTs, identified as TID 1, TID 2, and TID 3, were deployed. The signal for each, in the order they entered the water, were as follows: TID 1 started its signal at 20.5 seconds after every minute (GMT), TID 3 started its signal at 46.5 seconds after every minute, and TID 2 started its signal at 11.6 seconds after every minute. So, by adjusting the EMATTPingSequenceExample, a specific starting signal can be tailored to each EMATT.

E.   BATHYMETRIC AND TOPOGRAPHIC COLORING

The method for creating a bathymetric and topographic color scheme in X3D was modeled after the Fort Lauderdale, Florida example in Savage (https://savage.nps.edu/Savage/Locations/FortLauderdaleFlorida.x3d), where a Color node was attached to the ElevationGrid and the color definitions in the ecmascript were changed to a 64-color scale ranging from red (highest elevation) to purple (deepest depth) (Figure 20). The bathymetry generated for San Clemente Island can be viewed at

. A separate bathymetric and topographic scene of SCI was created in Rez using a slightly different color scheme (Figure 21).
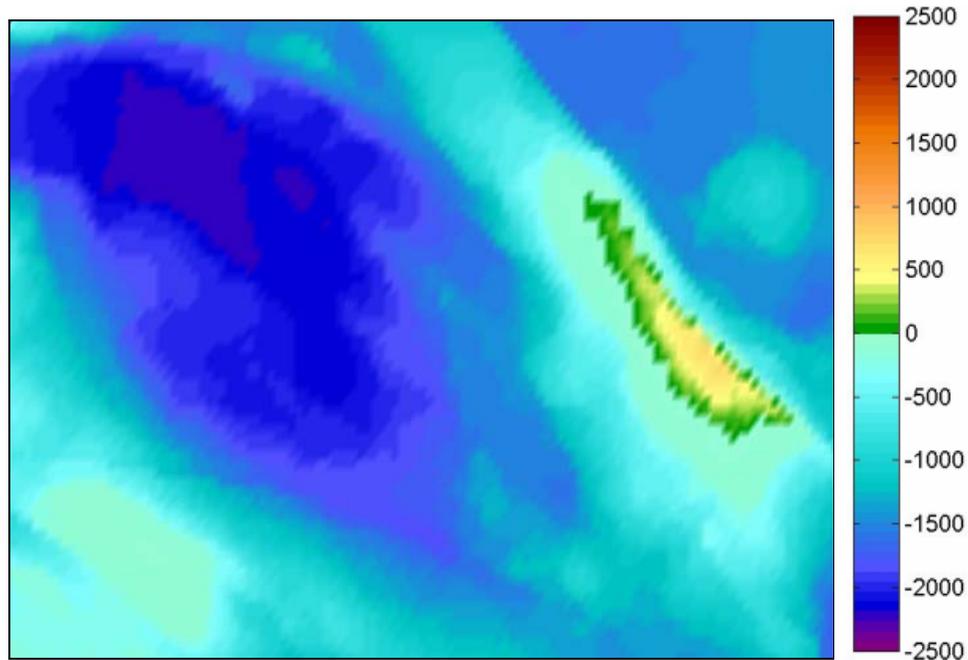
Figure 20. **Topography and bathymetry coloring of San Clemente Island and surrounding waters using NGDC 30-second data in X3D.**
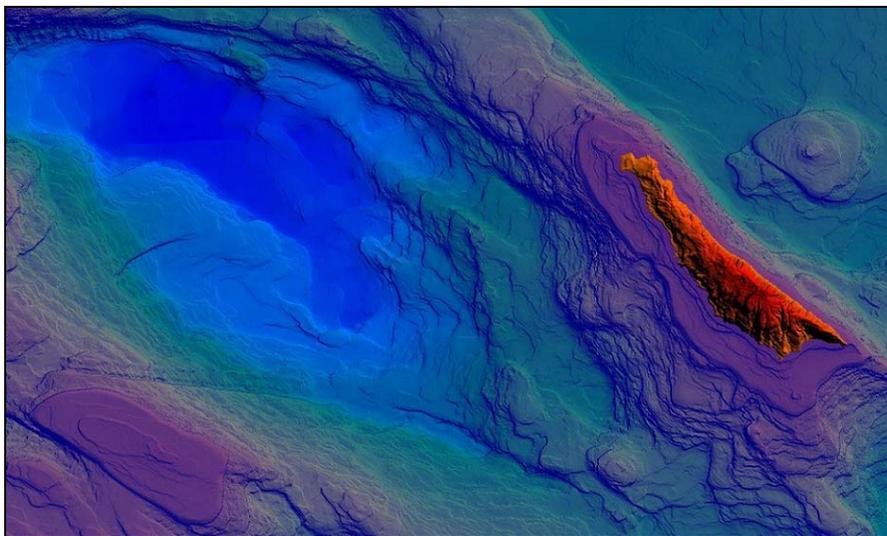
Figure 21. **Topography and bathymetry coloring of San Clemente Island and surrounding waters using NGDC 3-second data in Rez.**

F.   WAYPOINT INTERPOLATOR

The WaypointInterpolatorExample

(https://savage.nps.edu/Savage/Tools/Animation/WaypointInterpolatorExample.x3d)
prototype was used for animating RHIB and EMATT tracks. Real data were entered in
the ProtoInstance and TimeSensor sections: waypoints (XYZ format), legDurations
(point-to-point distances), legSpeeds (point-to-point speeds), lineColor,
highlightSegmentColor, outputInitializationComputations, and overall cycleInterval (total
time elapsed).

The WaypointInterpolator was used rather than the native PositionInterpolator
X3D node for a few reasons. The WaypointInterpolator allowed the user to see the
movement of the modeled object by showing a line of the entire distance covered. Also,
the WaypointInterpolator made it possible to control speed and turning rate. With the
PositionInterpolator, however, an object moved at the same rate in a rigid motion.

G.   DVD CONTROLLER

The DVD Controller in the Savage archive was incorporated into the scenes of
this thesis to allow the viewer to visualize elapsing time. The ExternProtoDeclare and
ProtoInstance were used, where the duration of each animation was entered as seconds in
the cycleInterval. The DVD Controller can be found at
https://savage.nps.edu/Savage/Tools/HeadsUpDisplays/DvdControllerExample.x3d.
Figure 22 illustrates this heads up display.
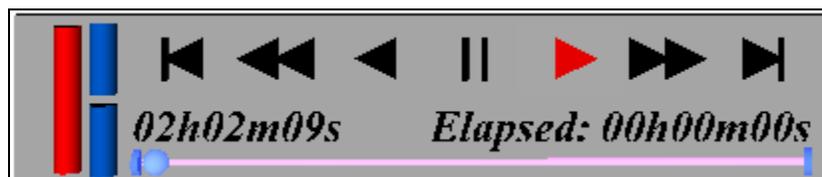
Figure 22.   DVD Controller heads up display found in the Savage model archive.

H. HYDROPHONE

A model of the hydrophone was made in Wings3D, based on a sketch of the MRSA Sensor Node in the "Multiplexed Range Sensor Array (MRSA) Production Training Manual" (1991). The hydrophone consisted of a tether and phone, created separately within Wings3D. After combining the two pieces together, the hydrophone was exported as a VRML file and then imported in Flux Studio, where the model was translated in the positive Y direction so that the bottom of the tether was at 0,0,0. When complete, the model was exported to X3D, and color was added to each part. The hydrophone is located in Savage Defense at

https://savagedefense.nps.navy.mil/SavageDefense/Locations/SanClementeIslandCalifornia/SCIHydrophoneExample.x3d. Refer to Figure 23 for a representation of a typical hydrophone found at SOAR.
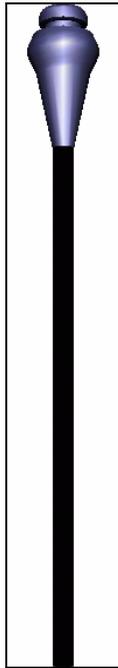
Figure 23.   Model of hydrophone used in Southern California Offshore Anti-Submarine Warfare Range.

I. WHALE

The Humpback whale was originally modeled with the Wings3D authoring tool (www.wings3d.com), based on the drawing http://inkart.net/art/wildlife_art/humpback_whale/Humpback-Whale.gif (Figure 24) used with permission.
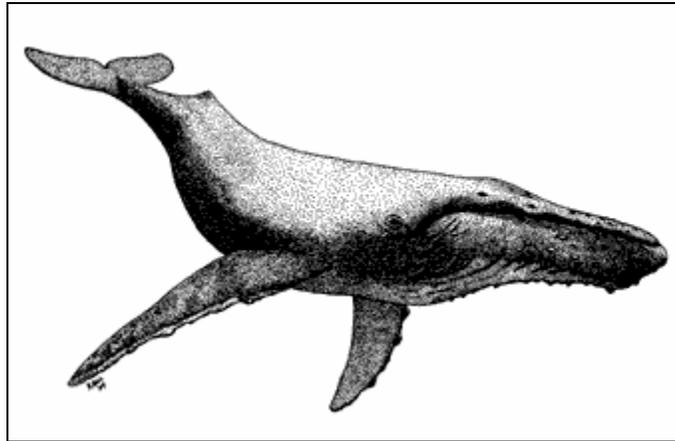
Figure 24. **Drawing of a Humpback whale used to model the whale in Wings3D (from http://inkart.net/art/wildlife_art/humpback_whale/Humpback-Whale.gif).**

The initial thought was to modify the dolphin model already in the Savage archive, but trial-and-error efforts determined that creating a whale from scratch was best. Starting from a cube shape, the head was made first, then the cube was extruded to make the body and tail. The fins and finer details of the hump on the back and mouth outline were made last. Lines were cut into smaller pieces, points were connected, sections were extruded, and beveling was used in areas to give the whale a rounded appearance. When making changes to one side of the whale, the same was done to the other side for symmetry purposes. Such a whale model took approximately nine hours to make in Wings3D. When finished, the whale was exported as a VRML file, then imported into the Flux Studio authoring tool (www.mediamachines.com). A texture was created by cutting and pasting an image of whale skin into an image editor. In Flux, this texture was downloaded, and the texturing option to repeatS and repeatT were unchecked. Because

this image gave the whale a striped appearance, it was necessary to "Drag to Scale" the texture to remove the lines. The final whale model can be viewed at https://savage.nps.edu/Savage/Biologics/Whales.x3d and in Figure 25.
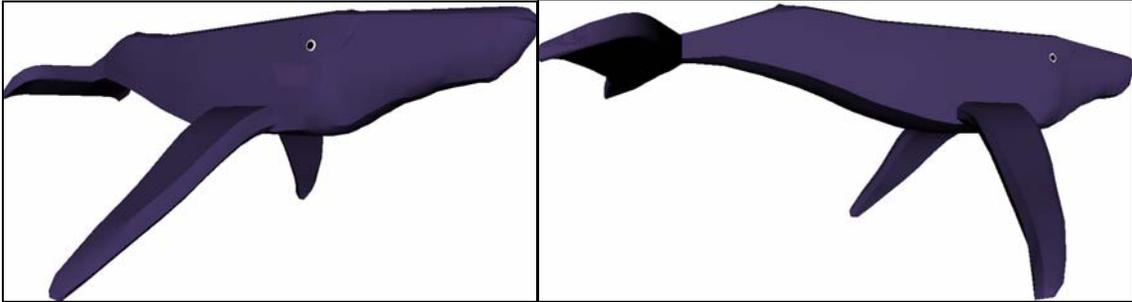
Figure 25.   **Humpback whale model seen from different views.**

J.   SUMMARY

The Savage and Savage Defense X3D model archives contain hundreds of models, and this chapter describes the process of modifying and incorporating them into this thesis. Those models include the RHIB, EMATT, EMATT Ping Sequence, Bathymetric Coloring, Waypoint Interpolator, and DVD Controller. In addition, the hydrophone and whale models created by the author are included.

V.   DATA-DRIVEN X3D MODEL ANIMATION

A.   INTRODUCTION

The data modeled in this thesis were obtained from many different sources. The EMATT tracking data were provided by SCORE, EMATT signal data were from the NPS Oceanography Acoustics lab, RHIB GPS plots came from Cascadia Research, and whale detections were provided by NUWC. All data sets are publicly releasable. This chapter discusses the steps taken to visualize and animate EMATT, RHIB, and whale data in each scene.

B.   ANIMATING EMATT DATA

The original Excel® file of the EMATT data included a lot of information, most of which was not needed for the purpose of this thesis. There were three EMATTs released at different times on 13 August 2004. Tracked by two systems, UWA and UWB, these EMATTs were on pre-programmed courses in the southern section of the SCORE range. The actual latitude and longitude coordinates for the EMATT tracks were recorded. However, the depth data were noisy because tracking accuracy was worse in the vertical direction, especially near range boundaries.

When it came to modeling this data, some smoothing was required before the final product could be viewed in X3D. First, the coordinates of the three EMATTs were separated into each system as six worksheets, corresponding to the two tracking systems. They were TID1_UWA, TID1_UWB, TID2_UWA, TID2_UWB, TID3_UWA, and TID3_UWB. Second, in each worksheet the latitudes and longitudes were converted into X and Z distances with respect to the northwest corner (0,0,0 origin), and the Y depths were converted into meters. Note, there were well over 1000 coordinate points for all six sets of data, covering a six hour time span.

Three graphs were made for the depths versus time (seconds), labeled DepthT1, DepthT2, and DepthT3 (Figures 32-34), where the UWA and UWB systems were

overlapped in two different colors. The same was done for latitude versus longitude (Figures 35-37). These graphs were later used to select 20-30 smoothed points for modeling each EMATT's track using the WaypointInterpolator in X3D. A sample of the selected points can be viewed in Appendix B Part C and D.

First, focusing on DepthT1, the points chosen from the EMATT Excel® file were ones where the tracking by the UWA and UWB systems overlapped. EMATT TID1 had been programmed for one depth change from 200 m to 400 m. Glancing at the graph, however, it appeared as if the EMATT made several up and down movements. These false fluctuations (effects of noise on acoustic tracking) may have been due to: 1) differences in tracking from one group of hydrophones to another, and/or 2) differences between the actual sound speeds and those assumed in SCORE calculations. Either way, such fluctuations in depth were taken into account in the point selection, along with points where the EMATT turned. Once the selected depths and times were recorded, the corresponding latitude and longitude coordinates were converted into X and Z. This XYZ data were then entered as waypoint values in the ProtoInstance node.

The next step was to find point-to-point distances, and the Excel® equation for Pythagorean Theorem was used. These values were entered as legDurations in the ProtoInstance node of the WaypointInterpolator.

To determine point-to-point speeds, it was necessary to calculate point-to-point times. This was a simple subtraction of times between each point. Point-to-point speed was then the division of point-to-point distance by point-to-point time. These values were entered as legSpeeds in the ProtoInstance node of the WaypointInterpolator.

The lineColor and highlightSegmentColor were changed in the ProtoInstance node in order to visualize which leg segment a moving object was on in the WaypointInterpolator.

In TimeSensor, the cycleInterval was the total elapsed time of the scene. Because actual data were modeled, running the scene at actual time was unreasonable. To speed up the animation, the elapsed time was divided by 100.

The last step in modeling EMATT TID 1 using the WaypointInterpolator was to make sure the four ROUTEs connected to the appropriate DEF nodes: from TimeSensor to ProtoInstance, from ProtoInstance to TimeSensor, and from ProtoInstance to the Transform node ('TrackingTransformTID1').

The above procedures were repeated for EMATTs TID 2 and TID 3. When each EMATT was rendered using the selected coordinates, the tracks still appeared jagged. This issue is discussed further in Chapter 6 "Problems Faced Along the Way."

C.   ANIMATING RHIB DATA

The GPS positions of the two RHIBs present during the Marine Mammal Species Verification Test were recorded every five minutes when they went out to sea during the study 10-21 August 2006. This information was provided by Cascadia Research in the form of an Excel® file, which in addition to latitude and longitude coordinates, included date and time columns. To incorporate this information into the X3D scene, the latitudes and longitudes had to be converted to distances in meters relative to the northwest origin (33.2º N 119.3º W). The Y positions were zero. Refer to Appendix B Part E for a sample of the converted RHIB data format.

To animate the tracks with the WaypointInterpolator, leg durations (point-to-point distances) and leg speeds were calculated. Leg durations were found using the Pythagorean Theorem calculation. To find leg speeds, the date and time were converted into seconds after 1 January 1970, which is the X3D standard. Point-to-point time was found by subtracting the previous seconds from the current point's time relative to the first data. Finally, point-to-point speed was point-to-point distance divided by point-to-point time. Appendix B Part E is a subset of the converted data necessary in animating the RHIBs.

D.   ANIMATING WHALE DATA

1.   Making Sense of the NUWC Data Format

The whale detection data used in this thesis were collected from the first of four Marine Mammal Verification Tests using the Marine Mammal Monitoring (M3R) system, maintained by the Naval Undersea Warfare Center (NUWC). Whale positions were sent by NUWC as a gnu zipped (.gz) archive file, containing binary position files (*.POS) and a utility to convert the binary files to text files. The data provided by NUWC were a subset of the position files from 10-21 August 2006, since the full set resided on the system at San Clemente Island.

The files were not organized in any particular fashion. For example, ARC-20060811T130816.txt, which was one of the largest files, contained over 32000 positions and covered a six-hour period (Figure 26), while other files contained data covering less spans of time.
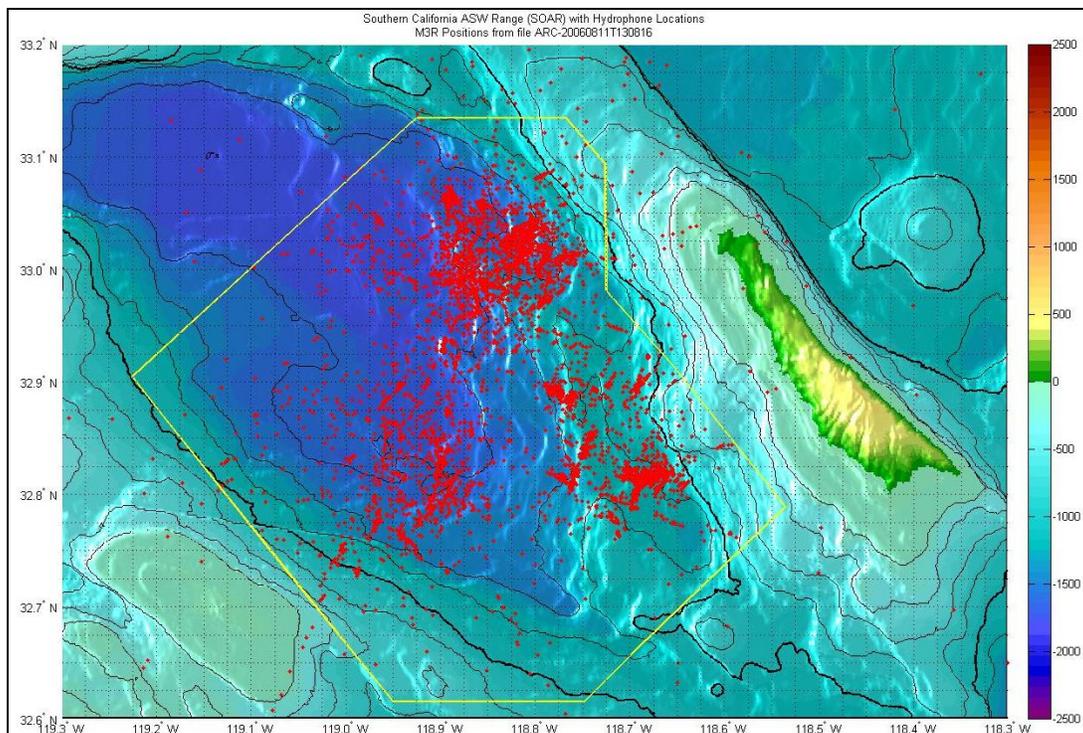
Figure 26.   Plotted whale detection data, labeled ARC-20060811T130816.txt.

Possible sources of error in the data set were provided by NUWC: 1) Fourteen of the hydrophones were identified as having +/- sign errors, and so any calculations based on them should be considered erroneous; 2) any position more than 5 nautical miles from the master hydrophone used to calculate this distance should be ignored. With these two criteria in mind, the data were filtered (Appendix A Part C). Plotting points for the same ARC-20060811T130816.txt file, green dots represented accurate locations, and red dots were considered suspect after filtering took place. Figure 27 displays the result.
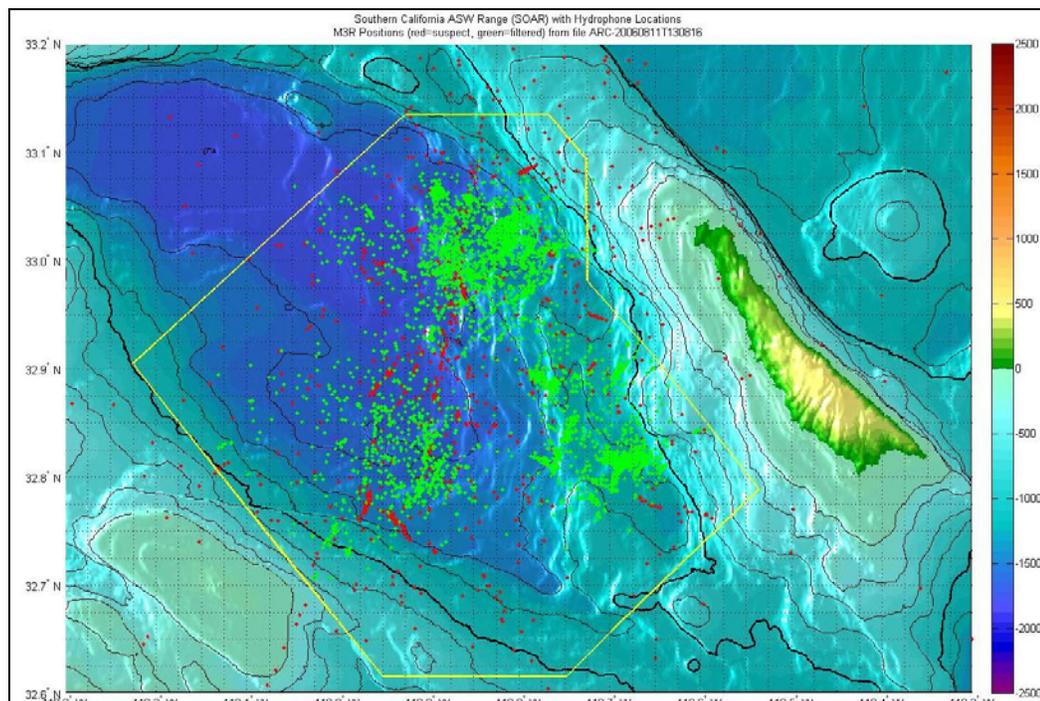
Figure 27.   **Plotted whale detection data from NUWC file ARC-20060811T130816.txt, where a set of criteria was used to eliminate points believed to be false targets (in red).**

Since this file covered a six-hour period, a third display was created to associate color with the order in which points appeared. The earliest data points were designated red, and later points were shades of orange and yellow, until the last points (relative to the start time of the file) were white. This still did not solve the issue of hundreds of points in the scene, making it difficult to discern any patterns in whale movement or sense of

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pod locations. In Figure 28, whale detection points over a six hour time span are displayed. For the purpose of this thesis, the NUWC data files were further separated into hourly files, as explained in the next section.
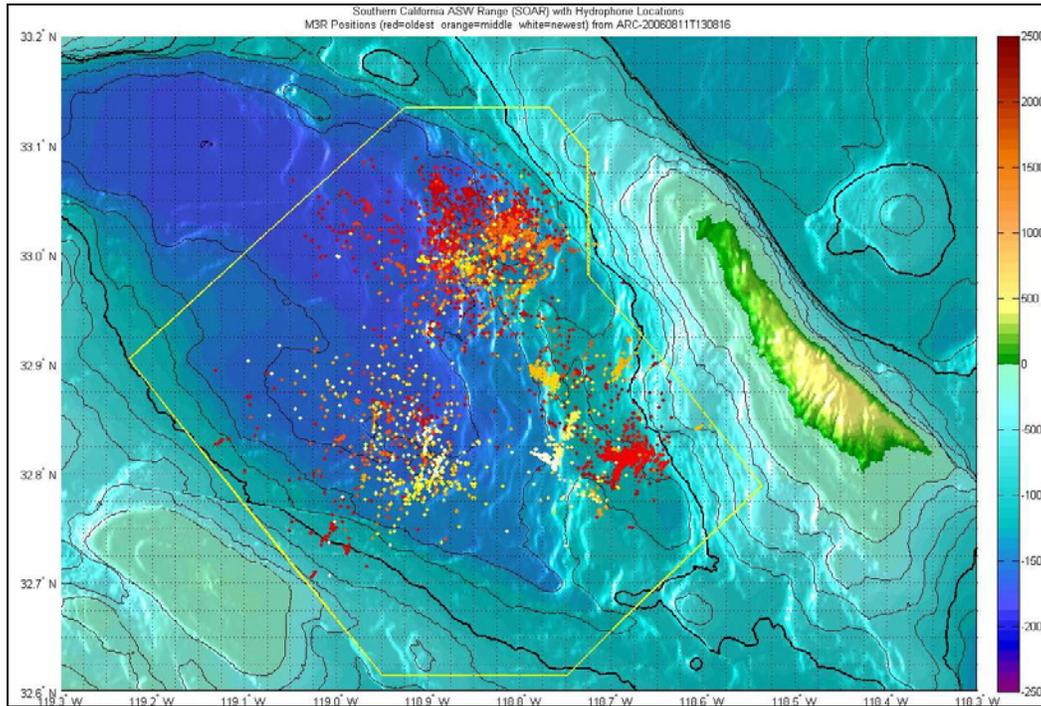
Figure 28.   **Plotted whale detection data from NUWC file ARC-20060811T130816.txt, where color is used to represent points in time (red being the earliest, transitioning to orange, yellow, then white).**

2.   Separating NUWC Data Files

The next step was to separate the NUWC whale tracking data into hourly .xls files. The earliest data point in the record was at 10 August 2006 22:56:55, and the last data point was at 18 August 2006 14:21:12. The MATLAB® code used to generate these files (Appendix A Part D) was a variation of what NUWC used to convert from .pos to .txt files. It read all the .txt files in the directory and filtered out the suspect data (same as before). Then, it found the earliest and latest data times in the full data set, starting with the whole hour before the earliest data (10 August 2200) and ending with the whole hour just before the last data point (18 August 1400). This ensured all data fit into one of the

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185 total .xls files created. Next, .xls filenames were created that covered all hours of the data period above, even if some files were not expected to receive any data. The reason for this was that the tracking system had been turned off at various times during the experiment for several hours, so many of the hourly files were blank. However, they were still generated in order to have a complete hour-by-hour time record for the X3D scenes. Each file was named based on its start time, preceded by "HR." This was the same time format as the "ARC" files.

3. Labeling New Hourly Files

The time-stamp used to make the NUWC "ARC" filenames was based on local time (Pacific Daylight Savings Time), while the time in the data was based on Greenwich Mean Time (GMT). This is a seven hour difference. For consistency purposes, all times were expressed as GMT, with data stored numerically as time since 1 January 1970 GMT (X3D reference time). To do this, the difference in seconds between the X3D standard (1 January 1970) and the NUWC standard (1 January 2006) was calculated (1136073600 seconds), and then added to the time recorded by NUWC (in seconds).

4. Creating JPEG Images of Plotted Hourly Files

A complete set of JPEG files covering the 185 hours of NUWC data was created in MATLAB® (Appendix A Part E). When saved into a new folder, they are viewed as a slideshow in Windows. The color code for the dots remained the same; red indicated detections early in the file, going to orange, yellow, and white as they occurred later in the file. In some cases, white dots turned red from one hour (file) to the next, indicating the same animals vocalizing going into the next hour. When comparing the files, some hours showed simple patterns while others were quite complex. In some sequences, there was a sense of moving patterns, but in others the detections seemed random. It is possible that finer sampling periodicity might improve the correlation between subsequent plots, since multiple groups of mammals are present, vocalizing and moving. It must be remembered, though, that the data collected from August 2006 occurred during

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the first of four tests conducted using the M3R system at SOAR. As a result, a lot of noisy data were recorded. The goal of NUWC is to improve the accuracy of data collection in future tests.

5.   Creating Movies from Three Selected Hourly Files

Another MATLAB® routine was created to sort data and generate one-minute JPEG images (Appendix A Part F). From this, a .wmf movie in Windows Movie Maker was made with imported JPEG pictures, covering three hours of marine mammal detections recorded on 14 August 2006 from 1400-1700 GMT. The movie started from scratch with one-minute of new data; in other words, there was no history of data prior to the start. Each subsequent frame added another minute of new data in the form of large, bright red dots. Some memory was retained from the previously displayed data, and as this data aged, the dots became smaller and darker until they disappeared after ten minutes. Figure 29 displays a snapshot from the animation.
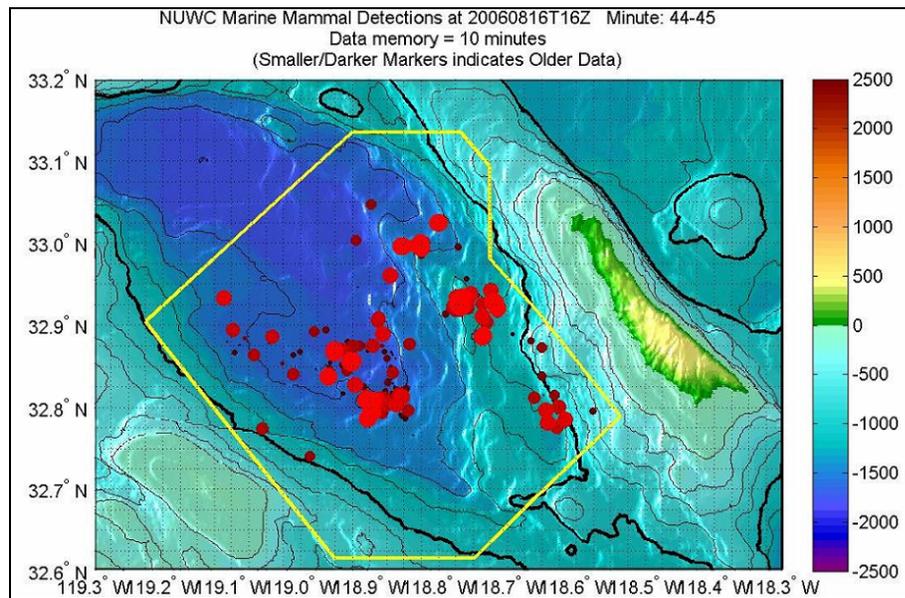
Figure 29.   Scene from a movie clip of whale detection data collected 14 August 2006, where points start as large bright red dots and then age to small dark red dots before disappearing.

This version of the movie did not give an indication of the six-level marine mammal classification scheme based on frequency that NUWC uses. Another movie was created for the same time frame, this time using a color scheme (Table 1) to indicate NUWC classification based on frequency ranges.

Red	-- High frequency (>42 kHz) broad band clicks (shouldn't see these at SCORE)
Yellow	-- Beaked whales = broadband clicks between ~24-48kHz
Green	-- "Dolphin" (or not beaked) = broadband clicks between ~12-48kHz
Cyan	-- sperm whale = broadband clicks between ~2-16kHz
Blue	-- Low frequency (<3 kHz) broad band clicks
Magenta	-- Whistles = anything at any frequency that is tonal (like a dolphin whistles!)

Table 1.   A color scheme created to indicate NUWC classification of frequency range detections.

The higher frequency (>42 kHz) and lower frequency (<3 kHz) categories were outside of the sensitivity range of SCORE hydrophones, and so the red and blue colors representing such frequencies were neither expected nor found in the movie. The majority of detections were classified as dolphin-like whistles (magenta), with a lesser amount of broadband clicks (cyan, yellow, and green). The classification system was far from perfect, though, due to the fact that the underlying test data probably included a lot of false detections. Thus, conclusions about the data should not be made based on this classification color scheme alone. See Figure 30 for a scene from the animation.
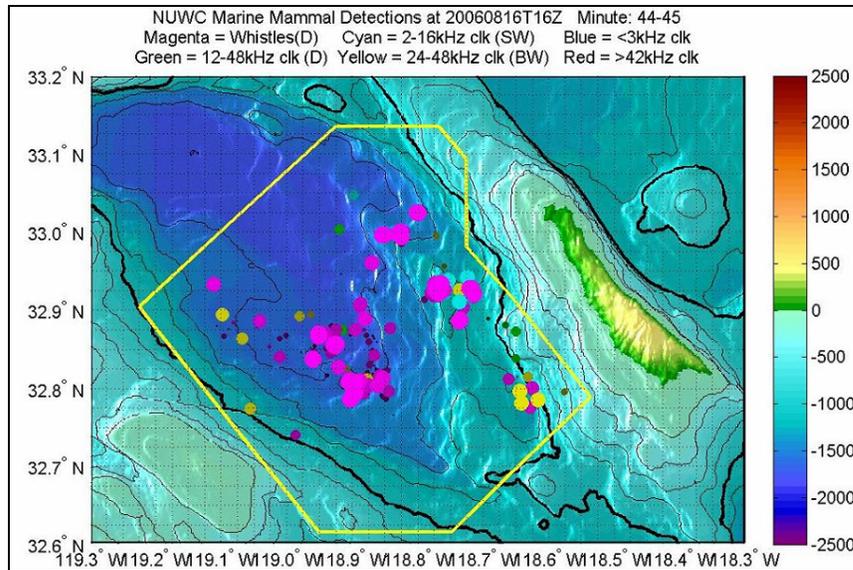
Figure 30. **Scene from a movie clip of whale detection data collected 14 August 2006 with a color scheme indicating frequency range.**

E. SUMMARY

This chapter describes how latitude, longitude, and time are standardized for the EMATT, RHIB, and whale data. Additional filtering of data was necessary for the EMATTs and whales, which rely on noisy acoustic tracking. This is done using MATLAB® routines and Excel® calculations, which are provided in Appendices A and B of this thesis.

VI. DISPLAY OF THE OVERALL SCENE

A. INTRODUCTION

This chapter discusses the compilation of bathymetry and topography data, hydrophones, SOAR boundaries, RHIBs, and whale detections into hourly segments, as well as the rationale for displaying eight scenes in this thesis.

B. THE FINAL SCENES

When the 185 hourly whale files were created, a decision was made on what events to use as example X3D scenes. The RHIB tracks had already been separated by day, so it was known when, where, and how many RHIBs were deployed (one or two). The next step was to separate the RHIB tracks by hour of each day. With the help of the 185 JPEG image files, whale detections were compared to the corresponding RHIB tracks for that time. The following observations were made: 1) The RHIBs were not in SOAR 11-13 August 2006, so it was not possible to visualize marine mammal reaction to the RHIBs; 2) there were no RHIB data collected for 15 August 2006; 3) the whale data for 18 August 2006 were not extensive enough while the RHIBs were on range to make any correlations. So, with 14, 16, and 17 August to choose from, the focus was on eight scenes: 14 August 2006 1600-2000 GMT and 16 August 2006 1600-2000 GMT. Each scene was labeled with SHR, followed by the start time year, month, day, and time. For example, the scene for 14 August 2006 1600-1700 GMT was labeled SHR20060814T1600 (Figure 31). See Appendix E for screenshots of all eight scenes.
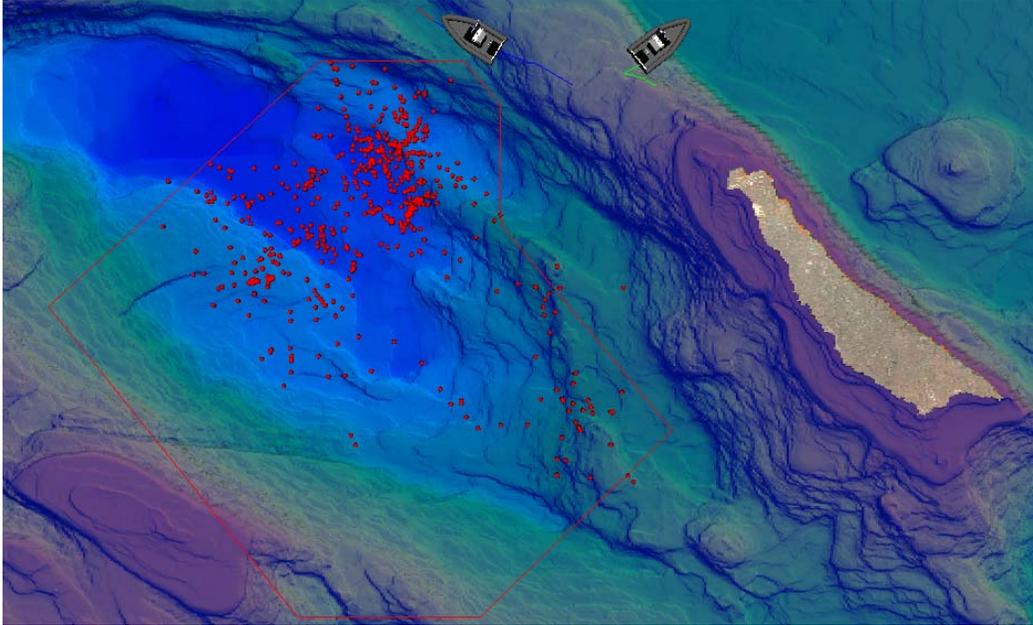
Figure 31. **Screenshot from scene SHR20060814T1600, depicting the presence of Cascadia RHIBs and whale vocalizations over a one hour time interval.**

Each SHR file contained all of the necessary scene components: RHIBs, WaypointInterpolators for the two RHIBs, ExternProtoDeclare for the hydrophone, Transform nodes with ProtoInstances for the 88 hydrophones, ElevationGrid node for bathymetry, SOAR boundary range, a ProtoDeclare for the whale detection, Transform nodes with ProtoInstances for whale detections, ExternProtoDeclare and ProtoInstance for the DVD Controller, and viewpoints. Each one of these components were later separated into their own files, given titles, and added to the Savage Defense model archive. They were then inlined into each SHR hourly scene. This construction pattern is suitable for automation to illustrate data collection in real time.

Plotting individual whale detection points by cutting and pasting their XYZ coordinates into each scene was labor-intensive, and this process needs to be fully automated. In the process of reviewing Excel® files, it was observed that the NUWC system generated redundant points with repeated time stamps (Appendix B Part F). A MATLAB® function was created to find all the lines with duplicate latitudes and longitudes, remove the duplicates, and save only the first occurrence. See Appendix A Part G.

A second MATLAB® function was created for future modeling of fading whale detection points (Appendix A Part H). In this routine, latitudes, longitudes, and times were checked for duplicates. If a detection occurred at the same location, but at a different time, it remained in the file because it may have represented an animal that stayed at the same spot but made multiple calls during that hour. This function will be useful when scenes are displayed as a function of time.

C.   SUMMARY

The components of this thesis were combined into eight scenes, representing 14 August 2006 1600-2000 GMT and 16 August 2006 1600-2000 GMT. Among the 185 hourly whale data files, these time frames were selected because RHIB GPS tracks were available. This chapter discusses the efforts of modeling whale detection points with the aid of a MATLAB® routine. Future work includes fully automating the production process.

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VII. PROBLEMS FACED ALONG THE WAY

A. INTRODUCTION

The purpose of this chapter is to describe the problems encountered and solutions applied when modeling the scene components of this thesis. The sections include Bathymetry, Hydrophone Positions, Waypoint Interpolator, EMATT Tracks, Whale Detections, Standardized Time, and Accuracy of Size and Scaling.

B. BATHYMETRY FORMAT

As stated in Chapter III, the origin of each ElevationGrid is located at the upper-left (northwest) corner of the grid. The grid is built west to east using only heights/depths (+/- Y). NGDC data were formatted the same way, and no adjustments to the data were needed. By contrast, the origin in the GeoElevationGrid is the southwest corner, and if used would have required reorganization to order the heights/depths correctly with respect to this different origin.

Another problem occurred when entering the NGDC heights/depths into the ElevationGrid. Initially, the six-second resolution data from the NGDC website were cut and pasted into the scene. However, when trying to render it, the file crashed. Apparently there is a 16000 limit in the X3D Specifications regarding the number of heights/depths one can input directly into ElevationGrid and GeoElevationGrid. In addition, there were problems with individual browsers that prevented the bathymetry from being displayed.

With these issues in mind, the X3D ElevationGrid node did not pose as an acceptable form for displaying bathymetry. As a result, the high-resolution three-second bathymetry was visualized in Rez.

C.   HYDROPHONE POSITIONS

The latitudes, longitudes, and depths of the 88 hydrophones were provided by SCORE. X and Z coordinates of the hydrophones were calculated on the premise that the total west-east distance across the scene was 93360 m (from 119.3º W to 118.3º W), and the total north-south distance was 66717 m (from 33.2º N to 32.6º N). This meant that the hydrophone positions had positive X and Z coordinates. Note, though, that for the west-east distance, an average value was used, which may have given a barely discernable distortion to the scene, causing hydrophone positions to appear slightly off from their reported locations.

The reported depths of the hydrophones were expected to place their bottoms directly on top of the bathymetry. However, this was not the case for some of the phones, and there may have been a couple of reasons for this. It may have been due to the xSpacing and zSpacing of the bathymetry, which were calculated by dividing the total distances of the scene into 120 increments (between 121-grid points) and 72 increments (73-grid points) respectively. Although minor, rounding calculations to the nearest meter may have caused some errors. Also, the surveyed hydrophone depths may not have matched the bathymetry precisely, due to the low-resolution scale used to depict the scene. This gave some hydrophones the appearance of floating just off the ocean bottom, while others appeared to be sinking into the bottom. No depth information for hydrophone 85 had been provided, so its Y position was adjusted to match bathymetry at this location

D.   WAYPOINT INTERPOLATOR

At first, a simple PositionInterpolator was considered for animating EMATT and RHIB tracks. This approach was insufficient for a number of reasons: 1) The PositionInterpolator did not allow the user to see where an object was over time because there was no visible track displayed; 2) there was no control over an object's speed, so if the user wanted to speed up a scene by 100, as was the case for the RHIBs, this was not possible; 3) there was no adjustment available for turning rate; rather, objects moved as rigid bodies with no pivoting in 3D space, causing object movement to appear unrealistic.

Due to these inherent limitations of the simple PositionInterpolator, the WaypointInterpolatorPrototype overcame these pitfalls and was used in this thesis.

The WaypointInterpolatorPrototype, however, was not free from its own limitations, which are discussed in this section. First, it required all leg speeds to be greater than zero, otherwise an error occurred. In the case of the RHIBs, though, there were several occasions when they had stopped to make visual observations. To overcome this obstacle, 0.00000001 replaced zero to indicate an object being motionless.

It is important to note that for the RHIBs, leg speeds entered in the WaypointInterpolator were averages, based on calculating leg durations over time. A RHIB's speed may have been somewhat greater or smaller within each time interval, but since GPS coordinates were recorded every five minutes, the distance traveled between points was the foundation for leg duration distances and therefore speeds. In terms of the EMATT tracks, however, there was an entirely different issue concerning leg speed. Because a select number of points were taken from the data and entered into X3D, the leg durations covered longer distances than they would have if all points were included. This affected speed because the time it took to cover one leg was not a simple calculation of distance over time. Instead, a generalization about what speed the EMATTs were programmed at was used, which was approximately five knots. There were other problems associated with the track selection of EMATTs, which are discussed later in this chapter.

The WaypointInterpolator did not appear to have a limit on the number of waypoints that can be entered, but in terms of rendering the scene, the browser took a long time to load when RHIB tracks reached 1000 coordinates. With a week's worth of data rendered in one scene, the tracks looked like a bowl of spaghetti. To alleviate such a clutter, the waypoint data were divided into hourly scenes, making rendering the scene easier. However, it caused a disconnection in observing RHIB movement and whale detections from one hour to the next. Recommendations for future work concerning the WaypointInterpolator are addressed in Chapter VIII.

E.   EMATT TRACKS

The EMATT tracking data for TID 1, TID 2, and TID 3 contained a lot of noise where the tracking systems lost lock on the EMATTs (Figures 32-34). In an effort to eliminate false data, points were discarded where recorded speed exceeded eight knots. Another source of error came from the fact that each good fix on an EMATT's position was calculated by data from different groups of hydrophones. The more hydrophones involved meant the better the fix; however there was still some measurement error (noise). Also, in the case of Figure 32, the TID 1 EMATT went beyond the last group of hydrophones in the southeast section of the SOAR range from 11000 to 16000 seconds after the launch of TID 1. As a result, the depth fixes became less accurate until the EMATT turned around and moved back into the hydrophone field. A final explanation for the lack of accuracy in EMATT coordinates may have been due to the tracking systems using different algorithms, causing the two sets of data to be different.
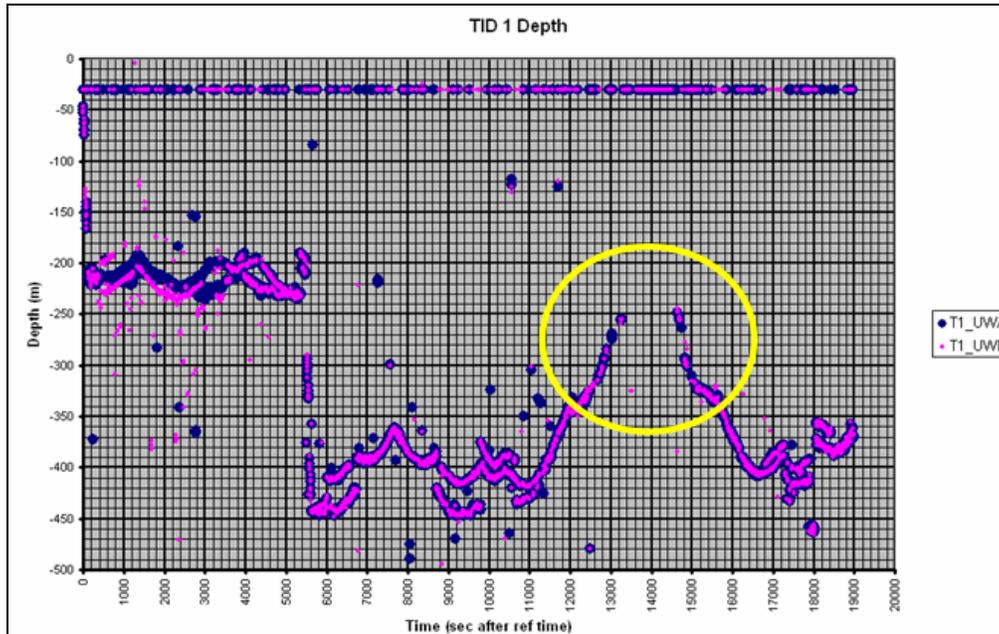
Figure 32.   Plotted EMATT depth data in Excel® for TID 1, where the EMATT went out of the hydrophone tracking range between 11000 and 16000 seconds after the launch of TID 1 (circled).

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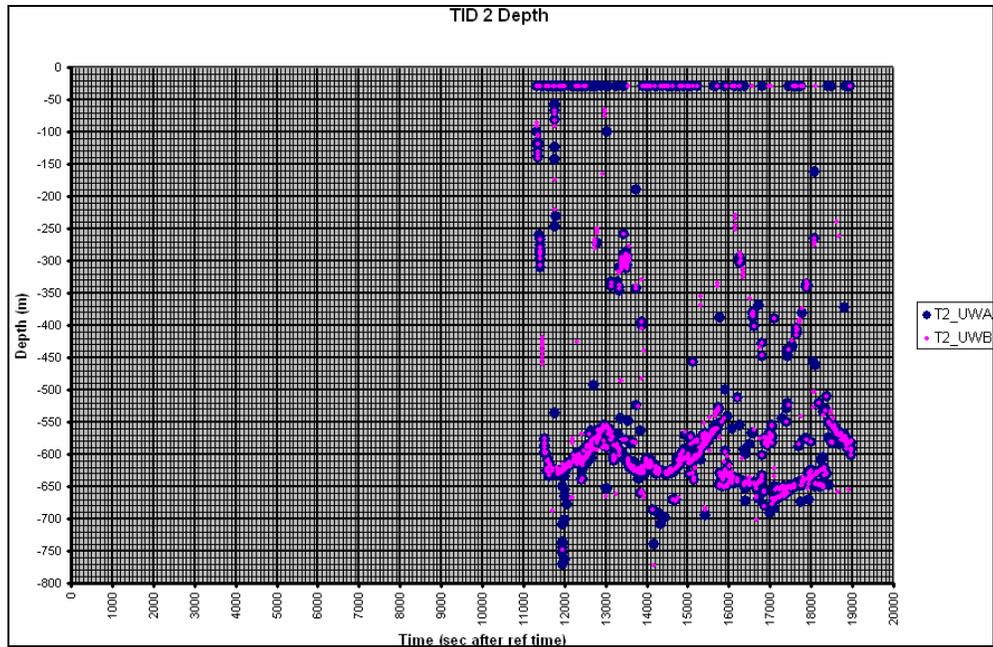
Figure 33. Plotted EMATT depth data in Excel® for TID 2, where Time = 0 represents the launch time of TID 1.
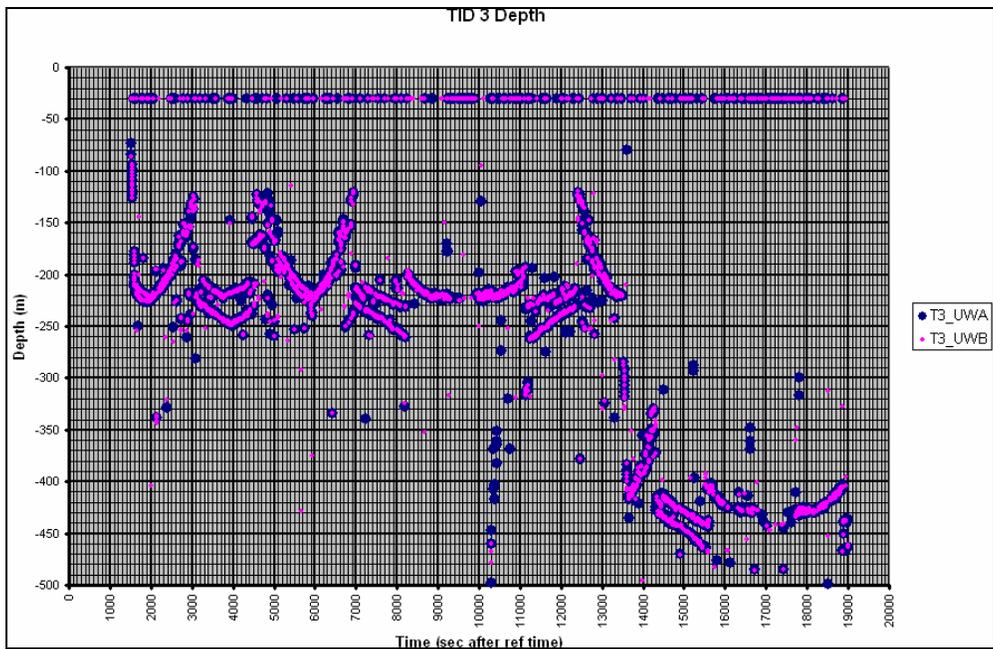
Figure 34. Plotted EMATT depth data in Excel® for TID 3, where Time = 0 represents the launch time of TID 1.

Despite a few attempts to select a given amount of points based on X and Z positions, as well as turning points (Figure 35-37), the EMATT tracks still appeared jagged (Figure 38).
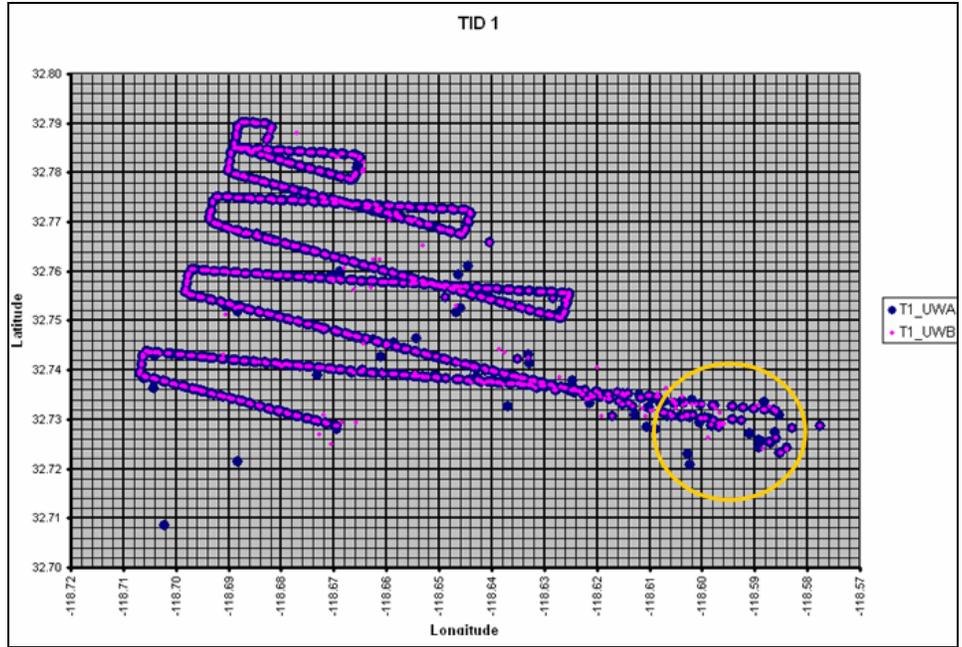
Figure 35. **Plotted EMATT track data in Excel® for TID 1. Note, the EMATT moved off range (circled), causing latitude and longitude fixes to become less precise.**
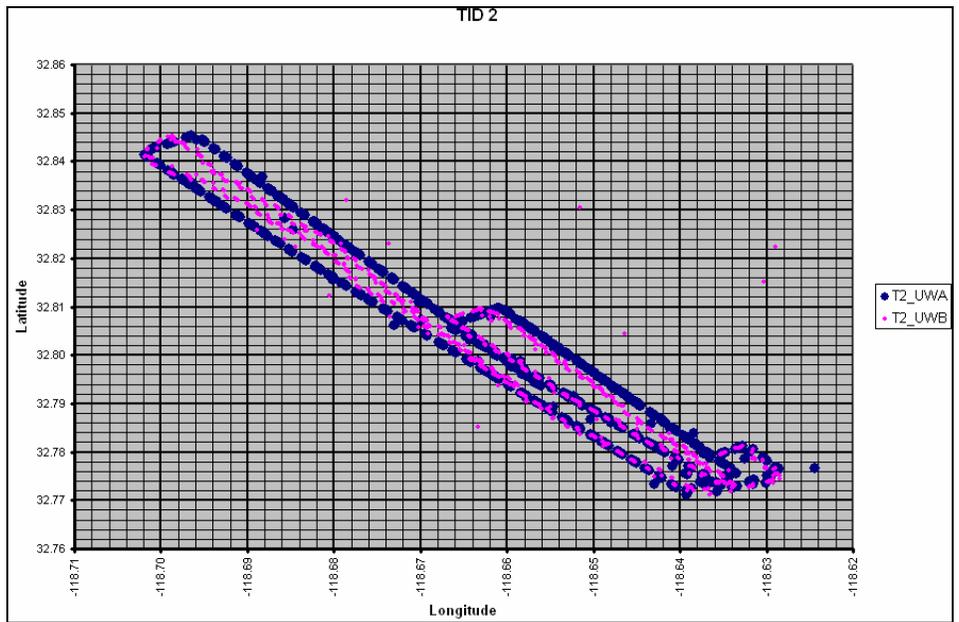
Figure 36. **Plotted EMATT track data in Excel® for TID 2.**
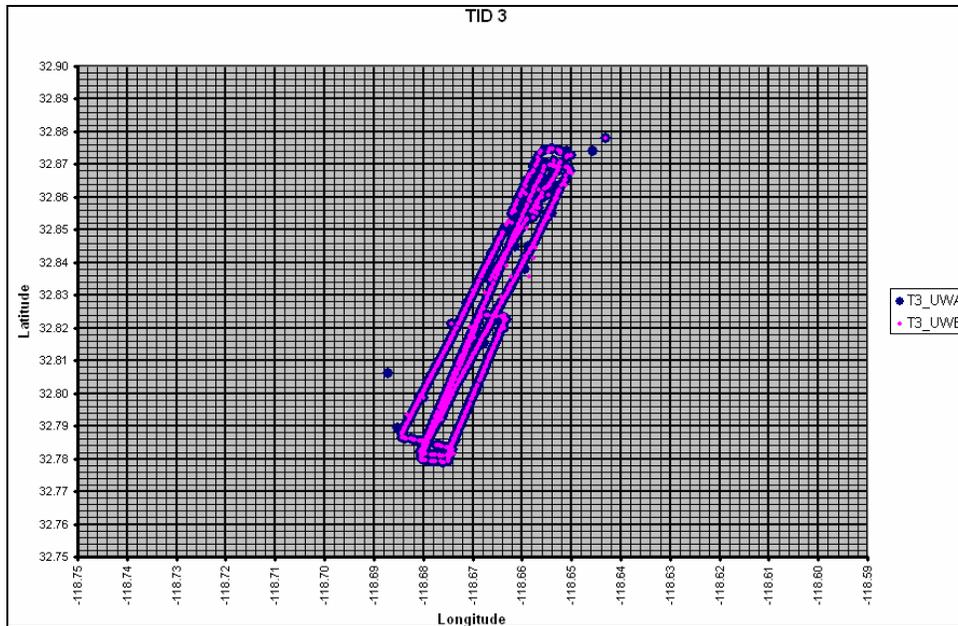
Figure 37. Plotted EMATT track data in Excel® for TID 3.

Although time-consuming, it might have been beneficial to further smooth the EMATT tracks by selecting more coordinates to be entered as waypoints in the WaypointInterpolator and then calculating corresponding leg durations and leg speeds.
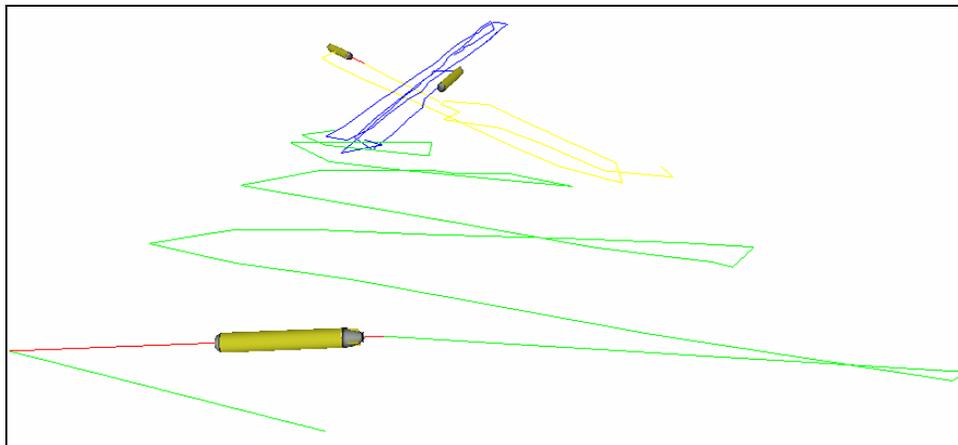
Figure 38. Selected points for modeling tracks of TID 1, TID 2, and TID 3 in X3D.

Plotting EMATT tracks was a stepping stone toward becoming familiar with the pitfalls associated with acoustic tracking data. One major dilemma involved the use of data in its raw versus filtered form: Should a modeler be given access to unfiltered data

with the choice to decide what to use in a scene, or should the data be presented in an already refined state, leaving the modeler nothing to do but model what is given? This particular modeling challenge occurs frequently and is addressed in Chapter VIII "Conclusions and Recommendations."

The next step in modeling acoustic data was the display of whale acoustic detections, where there were a lot of false detections included amongst the actual whale calls.

F. WHALE DETECTIONS

The process of recording whale detections by the NUWC M3R system is as follows: 1) When an individual whale or pod of whales vocalizes, the sound is received through multiple hydrophones; 2) this information is collected by NUWC software; 3) using the Time Delay of Arrival (TDOA) method, whale positions are calculated.

In the data provided by NUWC, some detections came from vocalizations of various animals in a pod, some from scattered individuals, and others were false alarms. There was no way of discerning what each point represented, but there were a couple of criteria used to filter the data. This did not eliminate all false alarms in the process, though, nor could the data be sorted in order to identify individual marine mammals. With the given data, the best thing to do was display the information as is. The intent was to allow behavioral scientists to analyze the data alone and glean their own conclusions from it, knowing that some false detections are likely still present.

Of the 185 hourly files created, some contained far more detections than others. There may have been several explanations for this anomaly: 1) The whales may have been more vocal at certain times of the day; 2) the whales may have tended to move to preferred ocean depths throughout the day, affecting the acoustic paths to the receivers; 3) the ocean structure may have varied throughout the day, also affecting the acoustic path to the receivers; 4) NUWC may have made adjustments to fine-tune their system throughout the study. These are all plausible reasons, but there is evidence supporting the last explanation.

Figure 39 summarizes where the data fell in time. The data were sorted into one-minute windows, then the number of detections that fell in each one-minute bin was counted. The X-axis of the plot represented each of the 185 hourly files, the Y-axis represented the 60 minutes in each of those hourly files, and the height of the peaks represented the number of data points that fell into each bin. It was apparent when data were recorded and when the system was turned off (indicated by flat areas in Figure 39). Note, there were several large peaks in the beginning, but as time progressed the number of detections smoothed out, suggesting there had been fine-tuning done on the system as the test proceeded.
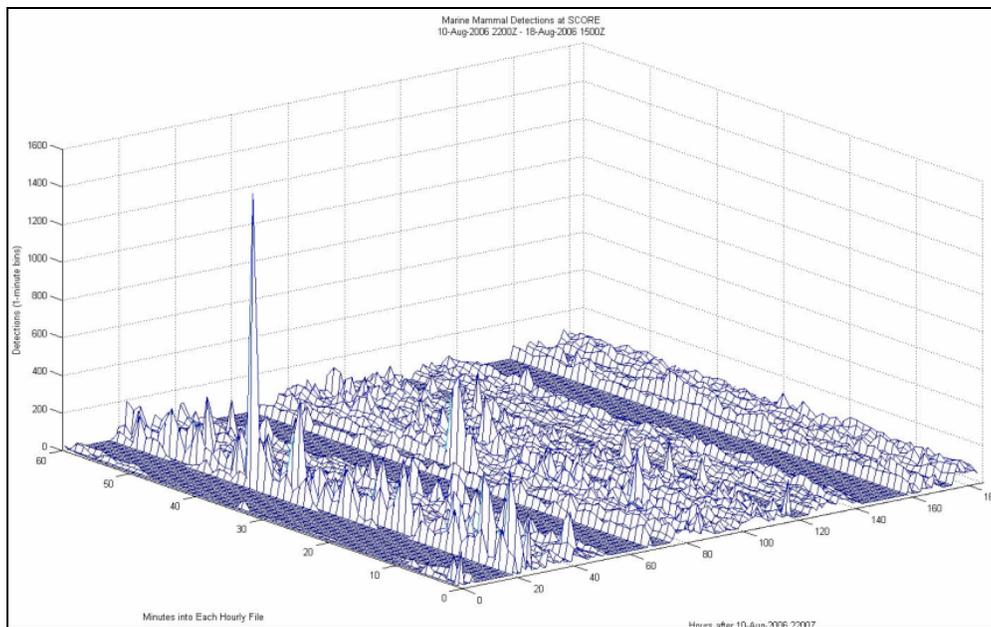
Figure 39. **Summary of where data fell in each of the 185 hourly files (X-axis) created from the NUWC data. The Y-axis represents the 60 minutes in each of these files, and the height represents the number of data points in each one-minute bin.**

G. STANDARDIZED TIME

In any situation where information from several different sources is collected and synthesized, there is the need to correlate data. The reference time was no exception in this thesis. RHIB and EMATT data had been recorded in Pacific Daylight Savings Time

(PDT), while the whale data were in Greenwich Mean Time (GMT) with data files labeled in PDT. The decision was made to reference all times in GMT using the X3D standard of 1 January 1970.

H.   ACCURACY OF SIZE AND SCALING

The dimensions of objects used in this thesis were captured as accurately as possible. Although height was not directly stated the "Multiplexed Range Sensor Array (MRSA) Production Training Manual," the modeled hydrophone was made approximately three meters tall. Since the EMATT model had been adapted from the REMUS example in Savage, its dimensions were kept the same. This was also true for the RHIB.

In terms of scaling, each object that needed to be viewed from a distance was exaggerated in size, since the area covered in the scene was 6,228,699,120 square meters. The only problem was that the scaling of one object was not relative to another. This did not pose too much of an issue, since the most important viewpoints were those that had a bird's eye perspective overlooking the entire scene. If more viewpoints were added with a closer look at RHIB positions, for example, then adjustments in scaling need to be made.

I.   SUMMARY

Most of the issues that arose in this thesis were related to the format and accuracy of the data itself. Other topics were directly related to X3D. This chapter, which addresses problems faced with bathymetry format, hydrophone positions, Waypoint Interpolator, EMATT tracks, whale detections, standardized time, and accuracy of size and scaling, are included so that future users are aware of them and that continued efforts may further improve these visualization techniques.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A.   CONCLUSIONS

This thesis demonstrates that X3D Graphics is an effective tool for modeling and visualizing San Clemente Island, SOAR, EMATT tracks, RHIB tracks, and whale vocalizations. The modeled data came from several different sources, and as a result there were issues of standardization addressed in this thesis. Final scenes visualized objects in geo-referenced and time synchronized format, but other problems involving data discrepancy and X3D shortcomings were experienced. Although there are improvements that can be made, this model is capable of providing baseline data analyses of marine mammal activity and reaction during on-range naval exercises. The auto-production of top level X3D scenes can be used in the future to repeat this visualization from live or recently collected data sources.

B.   RECOMMENDATIONS FOR FUTURE WORK

1.   High-resolution Bathymetry in GeoElevationGrid

The 30-second resolution of bathymetry data was used in this thesis because the number of data points was within the allowable X3D limit of data input. However, higher resolution of up to three seconds can be downloaded from the U.S. Coastal Relief Model Grids on the NGDC website and used in X3D if modified conversion scripts are developed in ElevationGrid, allowing data to be read directly from an Excel® file.

In addition, GeoElevationGrid can replace ElevationGrid in order to work in a latitude and longitude space, which is an advantage because this is the format of most data. GeoElevationGrid has four fields not found in ElevationGrid: geoSystem, geoGridOrigin, geoOrigin, and yScale.

In the meantime, Rez is used to visualize high-resolution NGDC data.

2.   Modified Waypoint Interpolator

Rather than seeing an object's entire track in the scene, a technique for fading in/out objects' tracks based on time is useful. For individual objects like RHIBs or EMATTs, it is beneficial to show just some of their past tracks (perhaps fading out after 500 m) and future tracks (fading in at 500 m), relative to their current positions, in order to give the viewer a perspective of where the object has been and is going.

In addition, a separate conversion script written within the WaypointInterpolator will allow waypoint coordinates to be read directly from an Excel® spreadsheet, saving a user the time and effort of copying and pasting XYZ coordinates into the scene.

3.   Filtered EMATT Data

In the original EMATT data provided from 13 August 2004, much of the tracking information on the three EMATTs' positions and speeds was less precise than desired, especially in the vertical direction. One must find a way to work with noisy data, be able to filter it, and present smooth tracks for such objects as acoustic sources.

Once this issue is resolved and data is ready to be modeled, there needs to be a way in X3D where objects appear and disappear at the right time. For example, as a scene progresses to the appropriate time to launch an EMATT, the EMATT needs to appear just as it is put into the water instead of seen idly waiting until it is time to move. Other EMATTs can appear at their designated launch times. Then hours later, as the tracking data ends, the objects will disappear from the scene. Such an approach is more realistic than having them sink to the bottom or stop moving in the scene when the objects are no longer being tracked. One method that might be implemented is the association of object scaling to waypoint coordinates. If the object has not been launched yet, its size can be scaled to .001 .001 .001 (XYZ) for example. At the time it enters the water and starts moving, its scale can be returned to normal at 1 1 1.

4.   Displaying Whale Data

The M3R passive acoustic monitoring hardware and software installed in July 2006 by NUWC was adjusted prior to the second Marine Mammal Species Verification Test conducted on San Clemente Island 11-22 April 2007, while Cascadia Research RHIBs drove through SOAR making visual observations. The tracking software was modified so that localizations matched the surface observations and did not produce excessive false detections. A follow-on test is tentatively scheduled for October 2007. In addition, there are plans for replacing SCORE hydrophones, whose frequencies do not cover below 8 kHz, with wideband (50 Hz- 45 kHz) hydrophones in 2009. With accurate data sets recorded by new hydrophones, X3D scenes will be able to model reality with precision.

In this thesis, the scenes displayed whale detections as red spheres by creating an ExternProtoDeclare, which defined the shape and appearance of the sphere. Then, transformation nodes containing ProtoInstances were added for each of the whale detection points in the hourly Excel® files. This was tedious, time-consuming work done by hand that can be replaced in the future with a text file written in MATLAB® that reads Excel® files for whale detection points.

Another area of improvement is allowing the red detection points to linger for a few minutes (five, ten, etc.) and then fade away as time progressed. This approach might give the viewer a sense of motion from pod vocalization or scattered individuals, as appropriate. Once this fading is accomplished, the color of the detection spheres can be changed to match the NUWC's classification scheme.

Finally, the capability to join multiple (at least two) hourly scenes to run as one larger scene with seamless transition will allow anyone using the model to make a better connection with what was going on over time. This can be accomplished by creating a master scene with a Switch node, connecting hourly scenes and displaying each scene for several seconds before moving on to the next hour.

5. Coordinated Efforts

The ultimate goal of this thesis was to develop a working visualization system that shows potential for correlating acoustic events (Navy sonar, ship noise, training targets, and other anthropogenic sounds associated with ASW training) and marine mammal reactions at SOAR. To accomplish such a mission, the location, time, duration of sound transmission events during a Navy acoustics exercise at SOAR, as well as concurrently recorded marine mammal location data derived from the fully operational NUWC M3R system, are required. Coordinated efforts between Command Third Fleet, SCORE, NPS, and possibly NUWC need to be established for developing a plan to mainstream production and delivery of X3D visualization products, mapping raw range data results into visualization scenarios for shipboard use.

Preferably, data from three or four similar exercises are desired, but one is minimal. It is also desirable to have marine mammal position data from one or two days before and after the exercise, in addition to the concurrently recorded data during the exercise. These can be snapshots covering several hours on each day, used to compare marine mammal population/behavior in active and inactive range environments.

6. Further Scene Details

When the above improvements are made to these scenes, then a follow-on effort might focus on modeling specific details of San Clemente Island and the SCORE range to include: hydrophone cable strings, SCI coast details such as piers and rock outcrops, island features like buildings, runways, roads, etc. (based on aerial/satellite imagery), ocean waves, and ships, planes, subs, weapons, etc. involved in exercises at SCORE, but not yet modeled in the Savage archive. The goal here is to continue improving scene fidelity to capture and display all factors and features of interest when visualizing both marine mammal and ship responses.

APPENDIX A. MATLAB® FUNCTIONS USED FOR DATA CONVERSIONS

A.   MATLAB® ROUTINE FOR LATITUDE AND LONGITUDE

The following MATLAB® routine was used for converting latitude and longitude into distances from the northwest reference point of the scene.

```
function ll2xz
% Purpose - translate position data from latitude/longitude to xz
positions
% wrt to the NW corner of ENS Thompson's X3D visualization model.
%
% Reference lat/lon position (NW corner) is 33.2  -119.3
% NE,SW,SE corners are: [33.2 -118.3],[32.6 -119.3],[32.6 -118.3]
% Positive x-direction is W->E, positive z-direction is N->S
%
% NGDC 30-sec bathymetry data are provided as 121x73 lat/lon grid.  X3D
% ElevationGrid uses a 121x73 flat rectangular grid.  To minimize
effects
% by not accounting for shape of the earth, an average value for W-E
% separation is used calculated from NW->NE and SW->SE corners.
%

nlat=33.2; slat=32.6; wlon=-119.3; elon=-118.3; % scene boundaries
dtop=deg2km(distance('rh',[nlat wlon],[nlat elon]))*1000;
dbot=deg2km(distance('rh',[slat wlon],[slat elon]))*1000;
dhor=round((dtop+dbot)/2);  % average horizontal
dver=round(deg2km(distance('rh',[nlat wlon],[slat wlon]))*1000);

% Calculate distance/degree (of longitude (dx) or latitude (dz)
dx=dhor/(elon-wlon);
dz=dver/(nlat-slat);

save('ll2xz','nlat','slat','wlon','elon','dx','dz')
```
ata.

B.   MATLAB® ROUTINE FOR READING THE HYDROPHONE FILE

This MATLAB® function read the hydrophone Excel® file, and like the previous function it converted latitude and longitude positions into distances with respect to the northwest corner. In addition, it converted depth of feet into meters.

```
function ll2xz
% Purpose - translate position data from latitude/longitude to xz
positions
% wrt to the NW corner of ENS Thompson's X3D visualization model.
%
% Reference lat/lon position (NW corner) is 33.2  -119.3
% NE,SW,SE corners are: [33.2 -118.3],[32.6 -119.3],[32.6 -118.3]
% Positive x-direction is W->E, positive z-direction is N->S
%
% NGDC 30-sec bathymetry data are provided as 121x73 lat/lon grid.  X3D
% ElevationGrid uses a 121x73 flat rectangular grid.  To minimize
effects
% by not accounting for shape of the earth, an average value for W-E
% separation is used calculated from NW->NE and SW->SE corners.
%
%
LLD=xlsread('Hydrophones.xls','LLD','A2:D85');
nlat=33.2; slat=32.6; wlon=-119.3; elon=-118.3; % scene boundaries
dtop=deg2km(distance('rh',[nlat wlon],[nlat elon]))*1000;
dbot=deg2km(distance('rh',[slat wlon],[slat elon]))*1000;
dhor=round((dtop+dbot)/2);  % average horizontal
dver=round(deg2km(distance('rh',[nlat wlon],[slat wlon]))*1000);

% Calculate distance/degree (in meters) in longitude (dx) and latitude
(dz)
dx=dhor/(elon-wlon);
dz=dver/(nlat-slat);

XZcoord=zeros(length(LLD),4);
XZcoord(:,3)=LLD(:,3); XZcoord(:,4)=LLD(:,4);
for i=1:length(LLD)
  XZcoord(i,1)=(nlat-LLD(i,1))*dz;
  if XZcoord(i,1)<0 || XZcoord(i,1)>dver
  disp('WARNING: Latitude not in scene')
  end
  XZcoord(i,2)=(LLD(i,2)-wlon)*dx;
  if XZcoord(i,2)<0 || XZcoord(i,2)>dhor
  disp('WARNING: Longitude not in scene')
  end
end
xlswrite('Hydrophones.xls', XZcoord, 'XZD');
```

C.   MATLAB® ROUTINE FOR FILTERING WHALE DATA

Many falsely detected whale data points were filtered with the MATLAB®
function below, while the rest of the points were saved.

```
function m3r_1h
% This function reads M3R data .txt files, remove suspect positions and
% writes the filtered data to hourly .xls files.  The filtering removes
the
% following positions:
```

```
%      a) those using H56, H64, H65, H66, H73, H74, H75, H76, H79, H80,
H81,
%         H82, H83 or H84 as master hydrophones before 2200 17Aug06 and
%      b) those that are >5nm from the master phone used to calculate
them
% These criteria for suspect data are described by Susan Jarvis in her
% READ.ME file included in the sample data set provided by NUWC from the
% Aug 2006 experiment.
%
% This program is a derivative of the m3r_pos2txt.m function written by
% Susan Jarvis to convert .POS binary data files to .txt format.  This
% modification was made by John E Joseph, NPS Ocean Acoustics Lab, Jan
2007

%% Find .txt files in the directory to read and time period covered
% find the number of data .txt files in directory
if (nargin < 1)
  txt_fn = ['ARC','*'];
end
files = dir([txt_fn '.txt']);
num_files = length(files);

% Determine time period covered by each .txt files
ct=0; mintime=1e8; maxtime=0; lohitimes=zeros(num_files,2);
for lp=1:num_files
    ct=ct+1;
    ftime=load(files(lp).name);
    lohitimes(lp,1)=min(ftime(:,4)/86400);
    lohitimes(lp,2)=max(ftime(:,4)/86400);
    if lohitimes(lp,1)<mintime
        mintime=lohitimes(lp,1); lct=num2str(ct);
    end
    if lohitimes(lp,2)>maxtime
        maxtime=lohitimes(lp,2); hct=num2str(ct);
    end
end
bdn=datenum('01-Jan-2006');
mindate=datestr(bdn+mintime);
maxdate=datestr(bdn+maxtime);
nfs=num2str(num_files);
disp(['Earliest date: ',mindate,' found in file number ',lct,' of
',nfs]);
disp(['Latest date:   ',maxdate,' found in file number ',hct,' of
',nfs]);

% make filenames for hourly .xls files based on time range in data files
%minfndate=datestr(floor(mindate*24)/24);
%maxfndate=datestr(ceil((maxdate*24)-1)/24);
ifn=(floor((bdn+mintime)*24):ceil(((bdn+maxtime)*24)-1))';
tst1=0; tst2=length(ifn);
for i=1:length(ifn)
    tst1=tst1+1;
    xls1h_fn(i,:)=datestr(ifn(i)/24,30);
end
disp([tst1 tst2]);
```

```
save('out','lohitimes','ifn','xls1h_fn')
```

D.   MATLAB® ROUTINE FOR DIVIDING NUWC FILES BY HOUR

Lengthy NUWC whale-detection data files were divided into hourly Excel®-spreadsheet files using the following MATLAB® function.

```
function m3r_filt1h(txt_fn,xls1h_fn)
% This function reads M3R data .txt files, remove suspect positions and
% writes the filtered data to hourly .xls files.  The filtering removes
the
% following positions:
%     a) those using H56, H64, H65, H66, H73, H74, H75, H76, H79, H80,
H81,
%         H82, H83 or H84 as master hydrophones before 2200 17Aug06 and
%     b) those that are >5nm from the master phone used to calculate
them
% These criteria for suspect data are described by Susan Jarvis in her
% READ.ME file included in the sample data set provided by NUWC from the
% Aug 2006 experiment.
%
% This program is a derivative of the m3r_pos2txt.m function written by
% Susan Jarvis to convert .POS binary data files to .txt format.

%% Find .txt files in the directory to read and time period covered
% find the number of data .txt files in directory
if (nargin < 1)
  txt_fn = ['ARC','*'];
end
files = dir([txt_fn '.txt']);
num_txtfiles = length(files);

% Determine time period covered by each .txt files
ct=0; mintime=1e8; maxtime=0; lohitimes=zeros(num_txtfiles,2);
for lp=1:num_txtfiles
    ct=ct+1;
    ftime=load(files(lp).name);
    lohitimes(lp,1)=min(ftime(:,4)/86400);
    lohitimes(lp,2)=max(ftime(:,4)/86400);
    if lohitimes(lp,1)<mintime
        mintime=lohitimes(lp,1); lct=num2str(ct);
    end
    if lohitimes(lp,2)>maxtime
        maxtime=lohitimes(lp,2); hct=num2str(ct);
    end
end
bdn=datenum('01-Jan-2006');
x3d_dn=datenum('01-Jan-1970');
mindate=datestr(bdn+mintime);
maxdate=datestr(bdn+maxtime);
nfs=num2str(num_txtfiles);
```

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```matlab
disp(['Earliest date: ',mindate,' found in file number ',lct,' of
',nfs]);
disp(['Latest date:   ',maxdate,' found in file number ',hct,' of
',nfs]);

% make filenames for hourly .xls files based on time range in data files
ifn=(floor((bdn+mintime)*24):ceil(((bdn+maxtime)*24)-1))';
for i=1:length(ifn)
    xls1h_fn(i,:)=(['HR-',datestr(ifn(i)/24,30)]);
    eval(['xpos',num2str(i),'=NaN(1,6);']);
end

% get hydrophone locations for filtering purposes
path(path,'H:\X3D\NUWCdata')
hydloc=xlsread('Hydrophones.xls','LLD','A2:B89');

% filter data based on NUWC's READ.ME file criteria
ctr=zeros(length(ifn),1);  % initialize counter for data separation
for lp = 1:num_txtfiles
    posit=load(files(lp).name);

    % filter out bad master hydrophone calculations
    [m,n]=size(posit);
    ptot(lp)=m;
    for i=1:m
        if posit(i,5)==56 || posit(i,5)==64 || posit(i,5)==65 || ...
                posit(i,5)==66 || posit(i,5)==73 || posit(i,5)==74 || ...
                posit(i,5)==75 || posit(i,5)==76 || posit(i,5)==79 || ...
                posit(i,5)==80 || posit(i,5)==81 || posit(i,5)==82 || ...
                posit(i,5)==83 || posit(i,5)==84
            posit(i,6)=NaN;
        end
    end
    ibmh=find(~isnan(posit(:,6)));
    posit=posit(ibmh,:);

    % filter out postions calculated >5nm from master hydrophone
location
    [p,q]=size(posit);
    bmh(lp)=m-p;
    for i=1:p
        sep=deg2nm(distance(posit(i,1),posit(i,2),...
            hydloc(posit(i,5),1),hydloc(posit(i,5),2)));
        if sep>5; posit(i,6)=NaN; end
    end
    ier=find(~isnan(posit(:,6)));
    posit=posit(ier,:);

    % determine what was filtered out
    [r,s]=size(posit);
    er(lp)=p-r;
    pcrej(lp)=100*(m-r)/m;

    % reorganize into hourly blocks of data
    posit(:,4)=posit(:,4)/86400 + bdn;
```

```
    for j=1:r
        for i=1:length(ifn)
            if posit(j,4)*24 >= ifn(i) && posit(j,4)*24 < ifn(i)+1;
                ctr(i,1)=ctr(i,1)+1;
                eval(['xpos',num2str(i),'(ctr(i,1),:)=posit(j,:);'])
            end
        end
    end
    disp(['Filtering complete on
',num2str(lp),'/',num2str(num_txtfiles),...
        ' .txt files']);
end
save('dumped','ptot','bmh','er','pcrej','xls1h_fn','ctr');
% Make hourly .xls files.  For empty blocks, add NaN to make a blank
.xls file
path(path,'H:\X3D\NUWCdata\XLS1HRfiles');
s1='.xls'; s2='H:\X3D\NUWCdata\XLS1HRfiles\';
for lp=1:length(ifn)
    s4=['xpos',num2str(lp)];
    if eval(['isnan(',s4,')'])
        eval(['xlswrite(''',s2,xls1h_fn(lp,:),s1,''',',s4,');']);
    else
        eval([s4,'(:,4)=(',s4,'(:,4)-x3d_dn)*86400;']);
        eval(['xlswrite(''',s2,xls1h_fn(lp,:),s1,''',',s4,');']);
    end
    disp(['Sorting ',num2str(lp),'/',num2str(length(ifn)),' .xls
files']);
end
return
```

E.   MATLAB® ROUTINE FOR CREATING JPEG FILES

The MATLAB® routine below was used for creating JPEG files covering the 185 hours of NUWC data.


```
function SCOREmapH
% Plots tracks, drop points or other significant locations on bathy
% and elevation background at SCORE.  Specifically designed to read
hourly
% NUWC tracking data to produce hourly jpeg images
%
%% Extract data based on source format
hr_fn = ['HR','*'];
files = dir([hr_fn '.xls']);
num_files = length(files);

%% Draw maps
% Things needed once....
soar=xlsread('H:\X3D\NUWCdata\SOARbox.xls','SOAR','B2:C18');
hydloc=xlsread('H:\X3D\NUWCdata\Hydrophones.xls','LLD','A2:C89');
tl1='Southern California ASW Range (SOAR) with Hydrophone Locations';
load H:\X3D\NUWCdata\clrmaps;
```

```matlab
load H:\X3D\NUWCdata\trackcolor;
% bathy prep
bathy=load('H:\X3D\NUWCdata\bathy.txt');
src=2; %src=input('Source of bathy data: 1=NAVO or 2=NGDC: ');
cs=2500; %cs=input('Colorscale range (+/- m): ');
bsrc='Naval Oceanographic Office';        % default source of bathy data
if src==2
    latb(:,1)=bathy(:,2);
    bathy(:,2)=bathy(:,1);
    bathy(:,1)=latb;
    bsrc='National Geophysical Data Center';
end
latmax=max(bathy(:,1));  latmin=min(bathy(:,1));
lonmax=max(bathy(:,2));  lonmin=min(bathy(:,2));
ind=find(bathy(:,1)~=bathy(1,1),1,'first');
m=round(ind-1);                            % number of longitudes
n=round(length(bathy)/m);                  % number of latitudes
lonBATHY=bathy(1:m,2);
latBATHY=bathy(1:m:length(bathy),1);
i=find(bathy(:,3)>1e5);    % NGDC uses 1e6 to indicate "no data"
bathy(i,3)=NaN;            % Change NGDC "no data" to NaN for Matlab
BD=reshape(bathy(:,3),m,n)';
[LONBATHY,LATBATHY]=meshgrid(lonBATHY,latBATHY);


%%  Draw hourly map frames
for indfn=1:num_files
    figure('Position',[50 150 1200 800]);
    set(gcf,'Colormap',BEcmap);
    axesm('mercator','Frame','on','FLatLimit',[latmin latmax], ...
     'FLonLimit',[lonmin lonmax],'Grid','on','MeridianLabel','on', ...
     'ParallelLabel','on','MLineLocation',.025,'MLabelLocation',.1, ...
     'PLineLocation',.025,'PLabelLocation',.1,'MLabelParallel','south',
...
     'MLabelRound',-1,'PLabelRound',-1)
    tightmap
    tl2=(['Hourly M3R Positions (red=oldest  white=newest) from ',...
    files(indfn).name(4:16)]);
    title({tl1,tl2});
    hold on

  % Display bathymetry
    geoshow(LATBATHY,LONBATHY,BD,'DisplayType','surface');
    daspectm('m',5); view(0,90); axis off;
    lightm(32.6,-118.3,1,'Style','infinite');
    lighting gouraud;
    %lightangle(75,75);
    material([.8 1 1]);
    caxis([-cs cs]);
    colorbar;

  % Contours at 200m increments, each 1000m in bold
    contour3m(LATBATHY,LONBATHY,BD,-1800:200:-200,'k');
    contour3m(latBATHY,lonBATHY,BD,-2000:1000:-1000,'k','LineWidth',2);
    set(gcf,'Renderer','OpenGL');
```

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```
    % plot hourly marine mammal tracking data
     mmpf=xlsread(files(indfn).name);
     [m,n]=size(mmpf);
     tmin=86400*(datenum(files(indfn).name(4:18),...
          'yyyymmddTHHMMSS')-datenum('01-Jan-1970'));
     ttot=3600;
     for i=1:m
          tfrac=round(63*(mmpf(i,4)-tmin)/ttot)+1;
          plot3m(mmpf(i,1),mmpf(i,2),mmpf(i,3),'LineStyle','none',...
              'Marker','.','MarkerEdgeColor',trackcolor(tfrac,:),...
              'MarkerFaceColor',trackcolor(tfrac,:));
     end

    % plot SOAR area and hydrophone locations
     plot3m(soar(:,1),soar(:,2),'y','LineWidth',2);
     plot3m(hydloc(:,1),hydloc(:,2),hydloc(:,3)+145,'yo');

    % make jpeg output
     jpgfig=fullfile('H:','X3D','NUWCdata','JPGfilesH',...
          files(indfn).name(1:16));
     print('-djpeg',jpgfig);
     close
     disp(['Frames completed: ',num2str(indfn),'/',num2str(num_files)]);
end
```

F.   MATLAB® ROUTINE FOR SORTING DATA TO MAKE A MOVIE

The following MATLAB® routine was used for sorting whale detection data and generating one-minute JPEG images, which were subsequently used to make two .wmf movies.

```
function SCOREmapM
% Plots tracks, drop points or other significant locations on bathy
% and elevation background at SCORE.  Specifically designed to read
hourly
% NUWC tracking data to produce 1-minute jpeg images
%
%% Extract data based on source format
tbeg_str=input('Start time (format> dd-mmm-yy HHMM): ','s');
tbeg=datenum(tbeg_str,'dd-mmm-yy HHMM');
tend_str=input('End time (format> dd-mmm-yy HHMM): ','s');
tend=datenum(tend_str,'dd-mmm-yy HHMM');
hr_fn = ['HR','*'];
files = dir([hr_fn '.xls']);
num_files = length(files);
basetime=86400*(datenum(files(1).name(4:18),'yyyymmddTHHMMSS')...
    -datenum('01-Jan-1970'));
if tbeg < datenum(files(1).name(4:18),'yyyymmddTHHMMSS')
    error('Start time < times covered in first file');
end
```

```
if tend >
datenum(files(length(files)).name(4:18),'yyyymmddTHHMMSS')+1/24
    error('End time > times covered in last file');
end
%% Draw maps
% Things needed once....
soar=xlsread('H:\X3D\NUWCdata\SOARbox.xls','SOAR','B2:C18');
hydloc=xlsread('H:\X3D\NUWCdata\Hydrophones.xls','LLD','A2:C89');
tl2='Magenta = Whistles(D)     Cyan = 2-16kHz clk (SW)      Blue = <3kHz
clk';
tl3='Green = 12-48kHz clk (D)  Yellow = 24-48kHz clk (BW)   Red = >42kHz
clk';
load H:\X3D\NUWCdata\clrmaps;
md01a=NaN(1,6); md01b=NaN(1,6); md01c=NaN(1,6);
md01d=NaN(1,6); md01e=NaN(1,6); md01f=NaN(1,6);
md02a=NaN(1,6); md02b=NaN(1,6); md02c=NaN(1,6);
md02d=NaN(1,6); md02e=NaN(1,6); md02f=NaN(1,6);
md03a=NaN(1,6); md03b=NaN(1,6); md03c=NaN(1,6);
md03d=NaN(1,6); md03e=NaN(1,6); md03f=NaN(1,6);
md04a=NaN(1,6); md04b=NaN(1,6); md04c=NaN(1,6);
md04d=NaN(1,6); md04e=NaN(1,6); md04f=NaN(1,6);
md05a=NaN(1,6); md05b=NaN(1,6); md05c=NaN(1,6);
md05d=NaN(1,6); md05e=NaN(1,6); md05f=NaN(1,6);
md06a=NaN(1,6); md06b=NaN(1,6); md06c=NaN(1,6);
md06d=NaN(1,6); md06e=NaN(1,6); md06f=NaN(1,6);
md07a=NaN(1,6); md07b=NaN(1,6); md07c=NaN(1,6);
md07d=NaN(1,6); md07e=NaN(1,6); md07f=NaN(1,6);
md08a=NaN(1,6); md08b=NaN(1,6); md08c=NaN(1,6);
md08d=NaN(1,6); md08e=NaN(1,6); md08f=NaN(1,6);
md09a=NaN(1,6); md09b=NaN(1,6); md09c=NaN(1,6);
md09d=NaN(1,6); md09e=NaN(1,6); md09f=NaN(1,6);
md10a=NaN(1,6); md10b=NaN(1,6); md10c=NaN(1,6);
md10d=NaN(1,6); md10e=NaN(1,6); md10f=NaN(1,6);

% bathy prep
bathy=load('H:\X3D\NUWCdata\bathy.txt');
src=2; %src=input('Source of bathy data: 1=NAVO or 2=NGDC: ');
cs=2500; %cs=input('Colorscale range (+/- m): ');
bsrc='Naval Oceanographic Office';        % default source of bathy data
if src==2
    latb(:,1)=bathy(:,2);
    bathy(:,2)=bathy(:,1);
    bathy(:,1)=latb;
    bsrc='National Geophysical Data Center';
end
latmax=max(bathy(:,1));  latmin=min(bathy(:,1));
lonmax=max(bathy(:,2));  lonmin=min(bathy(:,2));
ind=find(bathy(:,1)~=bathy(1,1),1,'first');
m=round(ind-1);                           % number of longitudes
n=round(length(bathy)/m);                 % number of latitudes
lonBATHY=bathy(1:m,2);
latBATHY=bathy(1:m:length(bathy),1);
i=find(bathy(:,3)>1e5);    % NGDC uses 1e6 to indicate "no data"
bathy(i,3)=NaN;            % Change NGDC "no data" to NaN for Matlab
BD=reshape(bathy(:,3),m,n)';
```

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```
[LONBATHY,LATBATHY]=meshgrid(lonBATHY,latBATHY);

%%  Draw hourly map frames
for indfn=1:num_files
    fdn(indfn)=datenum(files(indfn).name(4:18),'yyyymmddTHHMMSS');
end
iff=find(fdn<=tbeg,1,'last'); ifm=round(24*60*(tbeg-fdn(iff))+1);
ilf=find(fdn<tend,1,'last');  ilm=round(24*60*(tend-fdn(ilf)));
totfrm=(tend-tbeg)*24*60; ct=0;
for indfn=iff:ilf
    if indfn==iff; lm=ifm; else lm=1;  end
    if indfn==ilf; hm=ilm; else hm=60; end
    for indmin=lm:hm
        figure('Position',[50 150 1200 800]);
        set(gcf,'Colormap',BEcmap);
        axesm('mercator','Frame','on','FLatLimit',[latmin latmax], ...
         'FLonLimit',[lonmin lonmax],'Grid','on','MeridianLabel','on',
...
         'ParallelLabel','on','MLineLocation',.025,'MLabelLocation',.1,
...
         'PLineLocation',.025,'PLabelLocation',.1,...
         'MLabelParallel','south','MLabelRound',-1,'PLabelRound',-1)
        tightmap
        if indmin-1 < 10
            ml1=['0',num2str(indmin-1)];
        else
            ml1=num2str(indmin-1);
        end
        if indmin < 10
            ml2=['0',num2str(indmin)];
        else
            ml2=num2str(indmin);
        end
        tl1=(['NUWC Marine Mammal Detections at
',files(indfn).name(4:14),...
            'Z   Minute: ',ml1,'-',ml2]);
        title({tl1,tl2,tl3});
        hold on

      % Display bathymetry
        geoshow(LATBATHY,LONBATHY,BD,'DisplayType','surface');
        daspectm('m',5); view(0,90); axis off;
        lightm(32.6,-118.3,1,'Style','infinite');
        lighting gouraud;
        %lightangle(75,75);
        material([.8 1 1]);
        caxis([-cs cs]);
        colorbar;

      % Contours at 200m increments, each 1000m in bold
        contour3m(LATBATHY,LONBATHY,BD,-1800:200:-200,'k');
        contour3m(latBATHY,lonBATHY,BD,-2000:1000:-
1000,'k','LineWidth',2);
        set(gcf,'Renderer','OpenGL');
```

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```
% read 1-min increments of data, separate by classification
mmpt=xlsread(files(indfn).name);
tw=basetime+3600*(indfn-1)+60*(indmin-1);
clear md01
if isempty(mmpt)
    md01a=NaN(1,6); md01b=NaN(1,6); md01c=NaN(1,6);
    md01d=NaN(1,6); md01e=NaN(1,6); md01f=NaN(1,6);
else
    k=find(mmpt(:,4)>=tw & mmpt(:,4)<tw+60);
    md01(1:length(k),1:6)=mmpt(k,:);
    ka=find(md01(:,6)==1); kb=find(md01(:,6)==2);
    kc=find(md01(:,6)==3); kd=find(md01(:,6)==4);
    ke=find(md01(:,6)==5); kf=find(md01(:,6)==6);
    md01a=md01(ka,:); md01b=md01(kb,:); md01c=md01(kc,:);
    md01d=md01(kd,:); md01e=md01(ke,:); md01f=md01(kf,:);
    if isempty(md01a); md01a=NaN(1,6); end;
    if isempty(md01b); md01b=NaN(1,6); end;
    if isempty(md01c); md01c=NaN(1,6); end;
    if isempty(md01d); md01d=NaN(1,6); end;
    if isempty(md01e); md01e=NaN(1,6); end;
    if isempty(md01f); md01f=NaN(1,6); end;
end
% plot 10-min of each mammal classification
plot3m(md10a(:,1),md10a(:,2),md10a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.1 0 0],'MarkerSize',1);
plot3m(md10b(:,1),md10b(:,2),md10b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.1 .1 0],'MarkerSize',1);
plot3m(md10c(:,1),md10c(:,2),md10c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .1 0],'MarkerSize',1);
plot3m(md10d(:,1),md10d(:,2),md10d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .1 .1],'MarkerSize',1);
plot3m(md10e(:,1),md10e(:,2),md10e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .1],'MarkerSize',1);
plot3m(md10f(:,1),md10f(:,2),md10f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.1 0 .1],'MarkerSize',1);

plot3m(md09a(:,1),md09a(:,2),md09a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.2 0 0],'MarkerSize',2);
plot3m(md09b(:,1),md09b(:,2),md09b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.2 .2 0],'MarkerSize',2);
plot3m(md09c(:,1),md09c(:,2),md09c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .2 0],'MarkerSize',2);
plot3m(md09d(:,1),md09d(:,2),md09d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .2 .2],'MarkerSize',2);
plot3m(md09e(:,1),md09e(:,2),md09e(:,3),'LineStyle','none',...
```

```
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 0 .2],'MarkerSize',2);
plot3m(md09f(:,1),md09f(:,2),md09f(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.2 0 .2],'MarkerSize',2);

plot3m(md08a(:,1),md08a(:,2),md08a(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.3 0 0],'MarkerSize',3);
plot3m(md08b(:,1),md08b(:,2),md08b(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.3 .3 0],'MarkerSize',3);
plot3m(md08c(:,1),md08c(:,2),md08c(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 .3 0],'MarkerSize',3);
plot3m(md08d(:,1),md08d(:,2),md08d(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 .3 .3],'MarkerSize',3);
plot3m(md08e(:,1),md08e(:,2),md08e(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 0 .3],'MarkerSize',3);
plot3m(md08f(:,1),md08f(:,2),md08f(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.3 0 .3],'MarkerSize',3);

plot3m(md07a(:,1),md07a(:,2),md07a(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.4 0 0],'MarkerSize',4);
plot3m(md07b(:,1),md07b(:,2),md07b(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.4 .4 0],'MarkerSize',4);
plot3m(md07c(:,1),md07c(:,2),md07c(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 .4 0],'MarkerSize',4);
plot3m(md07d(:,1),md07d(:,2),md07d(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 .4 .4],'MarkerSize',4);
plot3m(md07e(:,1),md07e(:,2),md07e(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 0 .4],'MarkerSize',4);
plot3m(md07f(:,1),md07f(:,2),md07f(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.4 0 .4],'MarkerSize',4);

plot3m(md06a(:,1),md06a(:,2),md06a(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.5 0 0],'MarkerSize',5);
plot3m(md06b(:,1),md06b(:,2),md06b(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [.5 .5 0],'MarkerSize',5);
plot3m(md06c(:,1),md06c(:,2),md06c(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
        [0 .5 0],'MarkerSize',5);
plot3m(md06d(:,1),md06d(:,2),md06d(:,3),'LineStyle','none',...
        'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
```

```
        [0 .5 .5],'MarkerSize',5);
plot3m(md06e(:,1),md06e(:,2),md06e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .5],'MarkerSize',5);
plot3m(md06f(:,1),md06f(:,2),md06f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.5 0 .5],'MarkerSize',2);

plot3m(md05a(:,1),md05a(:,2),md05a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.6 0 0],'MarkerSize',6);
plot3m(md05b(:,1),md05b(:,2),md05b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.6 .6 0],'MarkerSize',6);
plot3m(md05c(:,1),md05c(:,2),md05c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .6 0],'MarkerSize',6);
plot3m(md05d(:,1),md05d(:,2),md05d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .6 .6],'MarkerSize',6);
plot3m(md05e(:,1),md05e(:,2),md05e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .6],'MarkerSize',6);
plot3m(md05f(:,1),md05f(:,2),md05f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.6 0 .6],'MarkerSize',6);

plot3m(md04a(:,1),md04a(:,2),md04a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.7 0 0],'MarkerSize',7);
plot3m(md04b(:,1),md04b(:,2),md04b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.7 .7 0],'MarkerSize',7);
plot3m(md04c(:,1),md04c(:,2),md04c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .7 0],'MarkerSize',7);
plot3m(md04d(:,1),md04d(:,2),md04d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .7 .7],'MarkerSize',7);
plot3m(md04e(:,1),md04e(:,2),md04e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .7],'MarkerSize',7);
plot3m(md04f(:,1),md04f(:,2),md04f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.7 0 .7],'MarkerSize',7);

plot3m(md03a(:,1),md03a(:,2),md03a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.8 0 0],'MarkerSize',8);
plot3m(md03b(:,1),md03b(:,2),md03b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.8 .8 0],'MarkerSize',8);
plot3m(md03c(:,1),md03c(:,2),md03c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .8 0],'MarkerSize',8);
```

```
plot3m(md03d(:,1),md03d(:,2),md03d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .8 .8],'MarkerSize',8);
plot3m(md03e(:,1),md03e(:,2),md03e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .8],'MarkerSize',8);
plot3m(md03f(:,1),md03f(:,2),md03f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.8 0 .8],'MarkerSize',8);

plot3m(md02a(:,1),md02a(:,2),md02a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.9 0 0],'MarkerSize',9);
plot3m(md02b(:,1),md02b(:,2),md02b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.9 .9 0],'MarkerSize',9);
plot3m(md02c(:,1),md02c(:,2),md02c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .9 0],'MarkerSize',9);
plot3m(md02d(:,1),md02d(:,2),md02d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 .9 .9],'MarkerSize',9);
plot3m(md02e(:,1),md02e(:,2),md02e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 .9],'MarkerSize',9);
plot3m(md02f(:,1),md02f(:,2),md02f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [.9 0 .9],'MarkerSize',9);

plot3m(md01a(:,1),md01a(:,2),md01a(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [1 0 0],'MarkerSize',10);
plot3m(md01b(:,1),md01b(:,2),md01b(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [1 1 0],'MarkerSize',10);
plot3m(md01c(:,1),md01c(:,2),md01c(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 1 0],'MarkerSize',10);
plot3m(md01d(:,1),md01d(:,2),md01d(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 1 1],'MarkerSize',10);
plot3m(md01e(:,1),md01e(:,2),md01e(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [0 0 1],'MarkerSize',10);
plot3m(md01f(:,1),md01f(:,2),md01f(:,3),'LineStyle','none',...
    'Marker','o','MarkerEdgeColor','none','MarkerFaceColor',...
    [1 0 1],'MarkerSize',10);

% plot SOAR area and hydrophone locations
plot3m(soar(:,1),soar(:,2),'y','LineWidth',2);
plot3m(hydloc(:,1),hydloc(:,2),hydloc(:,3)+145,'yo');

% make jpeg output for movie (can use Windows Movie Maker)
jpgfn=['Fig',files(indfn).name(4:14),'Z_m',ml1,'-',ml2];
jpgfig=fullfile('H:','X3D','NUWCdata','JPGfilesMC',jpgfn);
```

```
        print('-djpeg',jpgfig);
        close

        % Trickle down data for next picture
        clear md10a; md10a=md09a; clear md09a; md09a=md08a;
        clear md08a; md08a=md07a; clear md07a; md07a=md06a;
        clear md06a; md06a=md05a; clear md05a; md05a=md04a;
        clear md04a; md04a=md03a; clear md03a; md03a=md02a;
        clear md02a; md02a=md01a;

        clear md10b; md10b=md09b; clear md09b; md09b=md08b;
        clear md08b; md08b=md07b; clear md07b; md07b=md06b;
        clear md06b; md06b=md05b; clear md05b; md05b=md04b;
        clear md04b; md04b=md03b; clear md03b; md03b=md02b;
        clear md02b; md02b=md01b;

        clear md10c; md10c=md09c; clear md09c; md09c=md08c;
        clear md08c; md08c=md07c; clear md07c; md07c=md06c;
        clear md06c; md06c=md05c; clear md05c; md05c=md04c;
        clear md04c; md04c=md03c; clear md03c; md03c=md02c;
        clear md02c; md02c=md01c;

        clear md10d; md10d=md09d; clear md09d; md09d=md08d;
        clear md08d; md08d=md07d; clear md07d; md07d=md06d;
        clear md06d; md06d=md05d; clear md05d; md05d=md04d;
        clear md04d; md04d=md03d; clear md03d; md03d=md02d;
        clear md02d; md02d=md01d;

        clear md10e; md10e=md09e; clear md09e; md09e=md08e;
        clear md08e; md08e=md07e; clear md07e; md07e=md06e;
        clear md06e; md06e=md05e; clear md05e; md05e=md04e;
        clear md04e; md04e=md03e; clear md03e; md03e=md02e;
        clear md02e; md02e=md01e;

        clear md10f; md10f=md09f; clear md09f; md09f=md08f;
        clear md08f; md08f=md07f; clear md07f; md07f=md06f;
        clear md06f; md06f=md05f; clear md05f; md05f=md04f;
        clear md04f; md04f=md03f; clear md03f; md03f=md02f;
        clear md02f; md02f=md01f;

        ct=ct+1;
        disp(['Frames completed: ',num2str(ct),'/',num2str(totfrm)]);
    end
end
```

G. MATLAB® ROUTINE FOR FINDING DUPLICATE POSITIONS

The following MATLAB® routine was used for finding all lines in the hourly files with duplicate latitudes and longitudes, removing the duplicates, and saving only the first occurrence.

```
function dupdels
xfn='HR-20060814T160000.xls';
hd=xlsread(xfn);
for i=1:length(hd)
 if ~isnan(hd(i,1))
  j=find(hd(:,1)==hd(i,1) & hd(:,2)==hd(i,2));
  if length(j)>1
  hd(j(2:length(j)))=NaN;
  end
 end
end
k=find(~isnan(hd(:,1)));
hds=hd(k,:);
sfn=(['S',xfn]);
xlswrite(sfn,hds);
```

H. MATLAB® ROUTINE FOR FINDING DUPLICATE TIMES

The following MATLAB® routine was used for checking the hourly files for duplicates in latitudes, longitudes, and times. If a detection occurred at the same location, but at a different time, it remained in the file.

```
function dupdelj
xfn='HR-20060817T180000.xls';
hd=xlsread(xfn);
for i=1:length(hd)
 if ~isnan(hd(i,1))
  j=find(hd(:,1)==hd(i,1) & hd(:,2)==hd(i,2) & hd(:,4)==hd(i,4));
  if length(j)>1
  hd(j(2:length(j)))=NaN;
  end
 end
end
k=find(~isnan(hd(:,1)));
hds=hd(k,:);
sfn=(['J',xfn]);
xlswrite(sfn,hds);
```

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APPENDIX B. EXCEL® FILES

A.   INTRODUCTION

Sections of Excel® files used in this thesis are shown below to demonstrate the data from different sources: NGDC bathymetry and topography, selected EMATT points, Cascadia RHIB tracks, and NUWC whale detections. Compact discs of this publicly releasable data have been distributed to the NPS faculty Don Brutzman, Curt Collins, and John Joseph, and are available upon request.

B.   NGDC 30-SECOND BATHYMETRY AND TOPOGRAPHY DATA

The following Excel® file excerpt presents a section of the 30-second NGDC data used for creating the baseline of this thesis.

	A	B	C
1	-119.3	33.2	-215.8
2	-119.291667	33.2	-250.9
3	-119.283333	33.2	-376.1
4	-119.275	33.2	-401.9
5	-119.266667	33.2	-426.1
6	-119.258333	33.2	-461.7
7	-119.25	33.2	-471.5
8	-119.241667	33.2	-486.5
9	-119.233333	33.2	-542.8
10	-119.225	33.2	-655.2
11	-119.216667	33.2	-752.1
12	-119.208333	33.2	-800.3
13	-119.2	33.2	-821.1
14	-119.191667	33.2	-839.9
15	-119.183333	33.2	-876
16	-119.175	33.2	-998.2
17	-119.166667	33.2	-1047.8
18	-119.158333	33.2	-1105.9
19	-119.15	33.2	-1162.2
20	-119.141667	33.2	-1181.4
21	-119.133333	33.2	-1196.9
22	-119.125	33.2	-1213.5
23	-119.116667	33.2	-1221.6
24	-119.108333	33.2	-1228.5
25	-119.1	33.2	-1212.2
26	-119.091667	33.2	-1203.2
27	-119.083333	33.2	-1192.2
28	-119.075	33.2	-1182.4
29	-119.066667	33.2	-1186.9
30	-119.058333	33.2	-1190.2
31	-119.05	33.2	-1225.3
32	-119.041667	33.2	-1230.2
33	-119.033333	33.2	-1220.5
34	-119.025	33.2	-1217.4

30sec

C. SELECTED EMATT POINTS FROM ORIGINAL EXCEL® FILE

The following Excel® spreadsheet consists of selected points from the original TID 1 Excel® file, where latitude and longitude were converted to distances with respect to the northwest origin in the scene.

	A	B	C	D	E	F	G	H
1	Latitude	Longitude	X (m)	Depth (m)	Z (m)	Sec since 1-1-70	Min after 1st data	Sec after 1st data
2	32.786518	-118.682713	57629.91432	-30	45977.13099	1092382966	0.0000	0
3	32.78659	-118.682692	57631.87488	-30	45969.12495	1092382968	0.0333	2
4	32.786631	-118.682644	57636.35616	-30	45964.56596	1092382970	0.0667	4
5	32.786693	-118.682616	57638.97024	-46.56	45957.67187	1092382972	0.1000	6
6	32.786759	-118.682588	57641.58432	-50.29	45950.33299	1092382974	0.1333	8
7	32.786824	-118.682557	57644.47848	-52.43	45943.10532	1092382976	0.1667	10
8	32.786957	-118.682508	57649.05312	-58.05	45928.31639	1092382980	0.2333	14
9	32.78705	-118.682462	57653.34768	-62.57	45917.97525	1092382982	0.2667	16
10	32.787101	-118.682436	57655.77504	-63.35	45912.30431	1092382984	0.3000	18
11	32.787236	-118.682393	57659.78952	-68.33	45897.29298	1092382988	0.3667	22
12	32.787303	-118.682371	57661.84344	-71.34	45889.84292	1092382990	0.4000	24
13	32.787369	-118.682351	57663.71064	-74.95	45882.50405	1092382992	0.4333	26
14	32.788353	-118.682072	57689.75808	-30	45773.08817	1092383024	0.9667	58
15	32.78844	-118.682037	57693.02568	-127.79	45763.4142	1092383026	1.0000	60
16	32.788504	-118.682017	57694.89288	-130.88	45756.29772	1092383028	1.0333	62
17	32.788566	-118.681997	57696.76008	-134.62	45749.40363	1092383030	1.0667	64
18	32.788631	-118.681978	57698.53392	-136.5	45742.17596	1092383032	1.1000	66
19	32.788752	-118.681935	57702.5484	-140.18	45728.72136	1092383036	1.1667	70
20	32.788815	-118.681916	57704.32224	-143.67	45721.71608	1092383038	1.2000	72
21	32.788878	-118.681899	57705.90936	-145.78	45714.71079	1092383040	1.2333	74
22	32.789007	-118.68186	57709.5504	-152.03	45700.36664	1092383044	1.3000	78
23	32.78907	-118.681843	57711.13752	-154.57	45693.36135	1092383046	1.3333	80
24	32.789137	-118.681832	57712.16448	-160.88	45685.91129	1092383048	1.3667	82
25	32.789262	-118.681789	57716.17896	-166.25	45672.01191	1092383053	1.4500	87
26	32.750483	-118.872574	39904.49136	-30	49984.04282	1092383075	1.8167	109
27	32.789933	-118.682977	57605.26728	-208.78	45597.40007	1092383101	2.2500	135
28	32.789936	-118.683049	57598.54536	-210.31	45597.06648	1092383103	2.2833	137
29	32.78994	-118.683118	57592.10352	-210.29	45596.6217	1092383105	2.3167	139
30	32.789947	-118.683259	57578.93976	-211.43	45595.84334	1092383109	2.3833	143
31	32.789958	-118.683281	57576.88584	-215.01	45594.62019	1092383111	2.4167	145
32	32.790025	-118.684379	57474.37656	-30	45587.17013	1092383143	2.9500	177
33	32.790004	-118.684514	57461.77296	-216.52	45589.50522	1092383145	2.9833	179
34	32.790008	-118.684584	57455.23776	-216.86	45589.06044	1092383147	3.0167	181

081304_065153 / T1_UWA \ **T1_UWB** / T2_UWA / T2_UWB / T3_UWA / T3_UWB / T1_UWAc / T1

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D. CALCULATIONS FOR SELECTED EMATT POSITIONS

Time after the first data point, point-to-point distance, point-to-point time, and point-to-point speed were calculated for TID 1. The same was done for TID 2 and TID 3, though not displayed in this section.

S	T	U	V	W	X	Y
p2p distance	p2p time (sec)	p2p speed	speed	X	Depth Converted	Z
517.0682277	#VALUE!	#VALUE!	3.29	57603.12	-64.443864	45701.145
644.7724315	237	2.720558783	3.15	57136.32	-64.669416	45923.535
1648.265495	246	6.700266241	3.38	57603.12	-69.658992	46368.315
555.975	600	0.926625	3.15	59190.24	-63.65748	46813.095
186.72	177	1.054915254	3.04	59190.24	-62.28588	46257.12
1026.96	62	16.56387097	2.94	59003.52	-63.608712	46257.12
933.6	300	3.112	3.24	57976.56	-68.067936	46257.12
1078.740844	360	2.996502343	3.02	57042.96	-68.683632	46257.12
1168.929363	413	2.83033744	3.28	57789.84	-67.78752	47035.485
2308.587406	368	6.273335342	3.07	58910.16	-66.732912	47369.07
950.7010603	839	1.133135948	3.12	61150.8	-62.657736	47925.045
746.88	419	1.782529833	3.08	60310.56	-60.70092	47480.265
301.3455399	231	1.304526147		59563.68	-59.963304	47480.265
1587.12	115	13.80104348	3.13	59283.6	-62.627256	47369.07
1034.136455	475	2.17712938	3.28	57696.48	-69.110352	47369.07
2974.22111	545	5.45728644	3.5	56762.88	-91.77528	47813.85
1808.073239	976	1.852534057	3.15	59563.68	-121.176288	48814.605
1258.689038	586	2.147933512	3.1	61244.16	-118.926864	49481.775
217.3216198	428	0.507760794	2.97	62457.84	-113.769648	49815.36
580.763878	65	8.934828892	3.1	62644.56	-112.245648	49926.555
755.1119536	225	3.356053127	3.19	63018	-112.023144	49481.775
1311.761369	248	5.28936036	3.11	62271.12	-117.933216	49370.58
1684.154791	426	3.953415001	3.13	60964.08	-120.810528	49259.385
1125.824689	542	2.077167323	3.1	59283.6	-124.14504	49148.19
1120.32	360	3.112	3.13	58163.28	-126.269496	49036.995
904.0366197	346	2.6128226	3.19	57042.96	-123.39828	49036.995
1205.38216	421	2.863140522	3.09	56202.72	-125.245368	49370.58
1348.93755	432	3.122540625	3.01	57323.04	-124.718064	49815.36
3062.298593	429	7.13822516	3.06	58630.08	-127.068072	50148.945
2427.482607	998	2.432347302	2.97	61524.24	-102.906576	51149.7
217.3216198	829	0.262149119	3.01	63858.24	-89.56548	51816.87
4979.217196	1987	2.505896928	3.14	64044.96	-89.666064	51705.675
3275.159091	1577	2.076828847	3.08	59096.88	-121.389648	51149.7

E. CASCADIA RHIB DATA

Included is a screenshot of the RHIB GPS data, provided by Cascadia Research. The original Excel® file contained latitude, longitude, and time information. Conversions were made for distances with respect to the northwest corner of the scene, seconds after the first data point, point-to-point distance, point-to-point time, and point-to-point speed.

x	y	z		leg durations	leg speeds	p2p distance	seconds after 1st data	p2p time (sec)	p2p speed (m/s)
178067.39520	0	-606.01		22.88248191	0.397125007	22.88248191	0	#VALUE!	#VALUE!
178049.65680	0	-620.47		5.55975	0.020224311	5.55975	14	14	0.397125
178049.65680	0	-626.03		15.51204683	0.914703109	15.51204683	781	767	0.020224311
178035.65280	0	-632.70		274.4109324	0.718525737	274.4109324	1081	300	0.914703108
177859.20240	0	-842.86		215.5577214	4.594513001	215.5577214	1381	300	0.718525738
177650.07600	0	-895.12		1378.353899	10.49180227	1378.353899	1681	300	4.594512997
176569.90080	0	-38.92		3147.540684	12.2888787	3147.540684	1981	300	10.49180228
173466.61440	0	-564.87		3686.663608	12.28887867	3686.663608	2281	300	12.28887869
169814.37120	0	-1067.47		2637.129564	8.790431886	2637.129564	2581	300	8.790431879
167178.81840	0	-1158.65		967.3486458	3.224495483	967.3486458	2881	300	3.224495486
166213.47600	0	-1220.92		3065.522912	10.21840971	3065.522912	3181	300	10.21840971
163256.76480	0	-2030.42		1226.636389	4.088787965	1226.636389	3481	300	4.088787962
162143.91360	0	-2546.37		3771.947341	12.57315779	3771.947341	3781	300	12.5731578
159601.72080	0	-5332.91		4425.864558	14.75288187	4425.864558	4081	300	14.75288186
157199.56800	0	-9050.16		4462.452768	14.87484255	4462.452768	4381	300	14.87484256
154200.84480	0	-12354.88		4495.7382	14.98579401	4495.7382	4681	300	14.985794
150713.84880	0	-15192.57		1561.140347	5.203801148	1561.140347	4981	300	5.203801156
149880.14400	0	-16512.46		1758.334956	5.861116524	1758.334956	5281	300	5.861116519
149340.52320	0	-18185.94		2495.218857	8.317396184	2495.218857	5581	300	8.317396191
148717.81200	0	-20602.21		1328.798188	4.429327295	1328.798188	5881	300	4.429327292
149013.76320	0	-21897.63		607.3048518	2.024349508	607.3048518	6181	300	2.024349506
148915.73520	0	-21298.29		360.5199976	1.201733324	360.5199976	6481	300	1.201733325
148632.85440	0	-21074.79		300.0017839	1.000005947	300.0017839	6781	300	1.000005946
148910.13360	0	-20960.26		53.57734037	0.178591134	53.57734037	7081	300	0.178591135
148905.46560	0	-20906.88		565.983567	1.886611891	565.983567	7381	300	1.88661189
148940.94240	0	-21471.75		770.122471	2.567074899	770.122471	7681	300	2.567074903
149552.45040	0	-21003.62		142.187431	0.473958104	142.187431	7981	300	0.473958103
149685.95520	0	-20954.70		138.5930685	0.461976895	138.5930685	8281	300	0.461976895
149663.54880	0	-21091.47		2968.254755	9.894182526	2968.254755	8581	300	9.894182518
147456.51840	0	-23076.30		1721.748687	5.739162296	1721.748687	8881	300	5.739162291
146512.64880	0	-24516.27		2532.698637	8.442328783	2532.698637	9181	300	8.44232879
145213.07760	0	-26690.14		3531.791782	11.77263928	3531.791782	9481	300	11.77263927
142628.87280	0	-29097.51		1224.448221	4.081494068	1224.448221	9781	300	4.081494071
141658.86240	0	-28350.28		3552.196813	11.84065605	3552.196813	10081	300	11.84065604
138353.91840	0	-27048.18		3202.457962	10.67485986	3202.457962	10381	300	10.67485987
135231.02640	0	-26338.76		1811.446322	6.038154412	1811.446322	10681	300	6.038154408
133431.04560	0	-26542.25		1093.357979	3.644526593	1093.357979	10981	300	3.644526596
132338.73360	0	-26590.06		3741.000123	12.47000042	3741.000123	11281	300	12.47000041
129000.18000	0	-24902.12		3565.8818	11.88627268	3565.8818	11581	300	11.88627267
125460.90240	0	-24467.35		2669.875464	8.899584871	2669.875464	11881	300	8.899584878

F.   NUWC WHALE DATA

The following screenshot is an example of the August 2006 discrepancy in the NUWC system, where points with the same coordinates and time stamps were repeated multiple times throughout the file. This issue was resolved during the April 2007 test.

	A	B	C	D	E	F
473	32.8264	-118.63	0	1.16E+09	69	6
474	32.8271	-118.63	0	1.16E+09	69	6
475	32.9998	-118.718	0	1.16E+09	18	6
476	33.0398	-118.814	0	1.16E+09	17	6
477	32.9998	-118.718	0	1.16E+09	18	6
478	33.051	-118.877	0	1.16E+09	16	6
479	33.0145	-118.958	0	1.16E+09	24	2
480	33.0145	-118.958	0	1.16E+09	24	2
481	33.0145	-118.958	0	1.16E+09	24	2
482	33.0149	-118.755	0	1.16E+09	18	6
483	33.0398	-118.814	0	1.16E+09	17	6
484	32.824	-118.632	0	1.16E+09	69	6
485	32.8788	-118.887	0	1.16E+09	41	2
486	32.8788	-118.887	0	1.16E+09	41	2
487	32.8788	-118.887	0	1.16E+09	41	2
488	32.8183	-118.908	0	1.16E+09	58	2
489	32.8183	-118.908	0	1.16E+09	58	2
490	32.8252	-118.631	0	1.16E+09	69	6
491	32.8183	-118.908	0	1.16E+09	58	2
492	32.8183	-118.908	0	1.16E+09	58	2
493	32.8183	-118.908	0	1.16E+09	58	2
494	32.9147	-119.049	-269.77	1.16E+09	34	2
495	32.9147	-119.049	-269.77	1.16E+09	34	2
496	32.8258	-118.628	0	1.16E+09	69	6
497	32.9133	-119.047	0	1.16E+09	27	2
498	33.0668	-119	0	1.16E+09	11	3
499	32.8452	-119.062	0	1.16E+09	60	6
500	32.8453	-119.062	0	1.16E+09	60	6
501	32.8062	-119.093	0	1.16E+09	60	6
502	32.8243	-118.989	0	1.16E+09	41	2
503	32.8243	-118.989	0	1.16E+09	41	2
504	32.8243	-118.989	0	1.16E+09	41	2
505	32.8736	-119.012	0	1.16E+09	43	2
506	32.8243	-118.989	0	1.16E+09	41	2

I◄ ◄ ► ►I \ **Sheet1** / Sheet2 / Sheet3 /

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APPENDIX C. SAVAGE MODEL ARCHIVES

A.   INTRODUCTION

The Savage model archive contains over one thousand X3D models that are open source and available online. Some are complete models, some are model components, and all are reusable in composed scenes. The following section lists the available Savage model directories. Similar categories are also available for government-specific work as part of the Savage Defense X3D archive, which has access restricted to For Official Use Only (FOUO).

B.   SAVAGE OPEN SOURCE PUBLIC MODEL ARCHIVE

Savage

Scenario Authoring and Visualization for Advanced Graphical Environments

The Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) project is a large archive of dynamic 3D military models and authoring tools, all open source and built using Extensible 3D (X3D) graphics.

Zip archive   29 Sections, 165 Chapters, 1134 Models   Help

Aircraft Fixed Wing   Aircraft Helicopters   Aircraft Miscellaneous   Amphibious Vehicles   Auv Workbench   Avatars   Biologics   Buildings   Communications And Sensors   Environment   Ground Vehicles   Harbor Equipment   Harbors   Locations   Model Detailing   Offshore Structures   Robots   Scenarios   Ships Civilian   Ships Military   Space   Submarines   Tools   Weapons

Aircraft Fixed Wing

AV 8 B - Harrier - United States	Bear - Russia	C 130 - Hercules - Tunisia
Catalina	Euro Fighter	F 16 - Fighting Falcon - Turkey
F 18 - Blue Angel - United States	F 18 - Superhornet - United States	Jhl Heavy Lift - NPS
Mv 22 - Osprey - United States	P 3 Orion	

Aircraft Helicopters

AH 1 Super Cobra - United States	AH 1 W - United States	AH 64 DApache Longbow - United States
CH 46 E - Sea Knight - United States	CH 53 - United States	Helicopter - United States
Helix - Russia	Jhl Heavy Lift - NPS	MH 53 ESea Dragon - United States
OH 58 D - Kiowa Warrior - United States	SH 60 - Seahawk - United States	SH 60 B
SH 60 B - Seahawk - United States		

Aircraft Miscellaneous

Balloon	Blimp	Zeppelin

Amphibious Vehicles

AAAV   AAV   LCAC

Auv Workbench

AVCL   Operating Areas

Avatars

Marines

Biologics

Dolphin   Whales

Buildings

Erdc Two Story Building   House Baris Aktop   House Seksit Siripala
Playground   Soccer Stadium   UHRB
Zen Condominium

Communications And Sensors

Beam   Half Dome   Omni Directional
Satellite   Sea Web   Sonar
Sonobuoys   TRC 170   TSSR
WISP

Environment

Oceanography   Sea State   Time Of Day

Ground Vehicles

BMP 1   HMMWV   Jeep
M 1 A 1   M 1 A 2   M 2 A 3
M 577   MEFFV   MLRS 270
T 72 M   Truck   Wolverine

Harbor Equipment

Barrier   Brow   Buoys
Canopy   Chain Link Fence   Crane
Navigation Aids   Pier Riser   Table
Waterline Security Light

Harbors

Equipment

Locations

Camp Pendleton California   Fort Lauderdale Florida   Hawaii
Port Hueneme California   Rio De Janeiro   San Francisco California
Ship Island Mississippi   Southern California Border

Model Detailing

Hull Numbers

Offshore Structures

Oil Rigs

Robots

Jet Fire Transformer Toy   Unmanned Air Vehicles   Unmanned Ground Vehicles

Unmanned Surface Vehicles   Unmanned Underwater Vehicles

Scenarios

Amphibious Raid Camp Pendleton   Capture The Flag   Collision Uss Greeneville Mv Ehime Maru

Jfcom Dcee Exercise July 2003   Limited Objective Experiment Port Hueneme   Remus Mission 10 MAR 2003

Tank Maneuver   Uss Cole Terrorist Attack   UW 3303 Minefield Search

Ships Civilian

Barge   Cargo Ships   Cigarette Boat

Cruise Ship   Ferries   Hovercraft - Singapore - SNR 6

Merchant Livestock Carrier   Personal Water Craft   Sail Boats

Small Craft   Supertanker   Trawlers

Tugboats

Ships Military

Carrier - Independence - United States   Carrier - Nimitz - United States   Carrier - Saratoga - United States

Cruiser - United States   DD 963 - Spruance - United States   DDG - 51 Flight IIA - United States

DDG - Arleigh Burke - United States   Destroyer - Sovremenny - Russia   FFG - 7 Oliver Hazard Perry - United States

FFG - Oilver Perry - United States   FFG - Oliver Perry - United States   Frigate - Greece

Frigate - Greece - MEKO 200   Frigate - Yavuz - Turkey   Harbor Ferry Boat

Hovercraft - Singapore - SNR 6   Landing Platform Dock - LPD   Landing Ship Tank - Endurance - Singapore

Large Deck Amphib - Boxer - United States   Missile Attack Boat Osa II   Patrol Craft - Greece - Vosper

Patrol Craft - Russia - Nanuchka - Lighthouse   Patrol Craft - United States - Tempest   RHIB - United States

Running Lights   Sea Base

Space

Satellite Lab   Shuttle   Solar System

Space Attack

Submarines

Periscope Reticle   SSGN - Ohio - United States   SSN - Los Angeles - United States

Various

Tools

Animation   Authoring   Exercise Clock

Explosions   Heads Up Displays   SMAL

Symbology   Terrain   VRML 1

Weapons

Ammunition   Crew Served Weapons   Guns

Missiles   Small Arms   Torpedoes

Underwater Mines

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APPENDIX D. SELECTED JPEG FILES FROM HOURLY WHALE DATA FILES

A.   SHR20060814T1600 JPEG (14 AUGUST 2006 1600 GMT)

Whale detections were plotted in a JPEG file for 14 August 2006 1600 GMT.
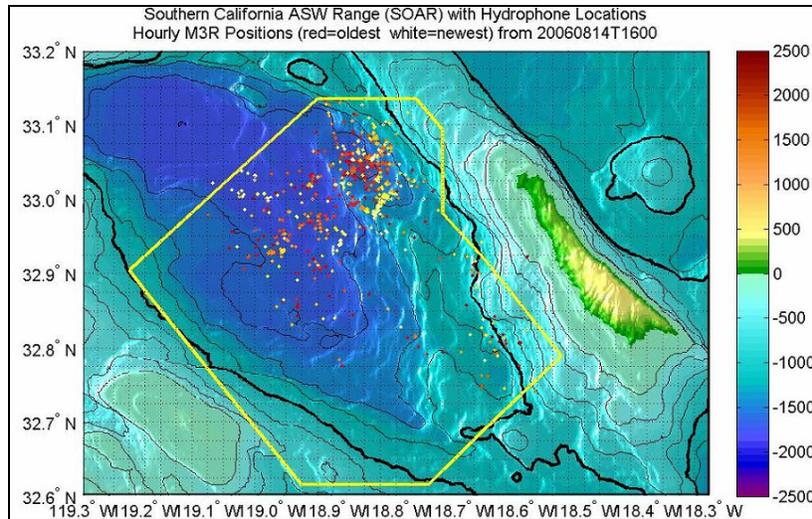

B.   SHR20060814T1700 JPEG (14 AUGUST 2006 1700 GMT)

The following JPEG image represents whale detections for 14 August 2006 1700 GMT. Note, the NUWC system was shut off at this hour.
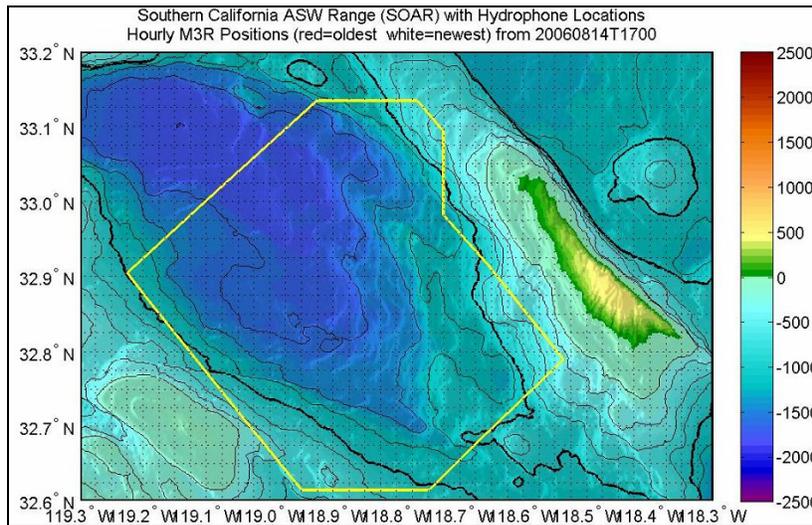
C. SHR20060814T1800 JPEG (14 AUGUST 2006 1800 GMT)

The NUWC system was shut off on 14 August 2006 1800 GMT, as seen below.
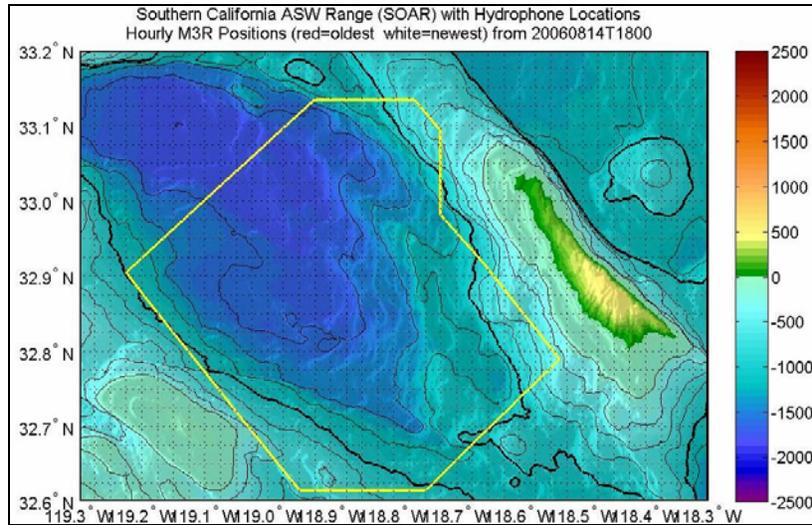
D. SHR20060814T1900 JPEG (14 AUGUST 2006 1900 GMT)

The NUWC system was turned back on 14 August 2006 1900 GMT, but there were few whale detections recorded.
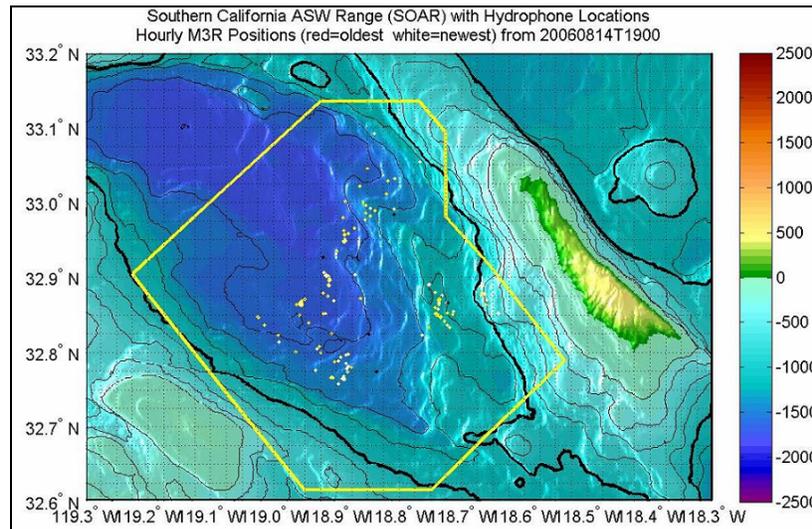
E.   SHR20060816T1600 JPEG (16 AUGUST 2006 1600 GMT)

There were many whale detections recorded on 16 August 2006 1600 GMT.
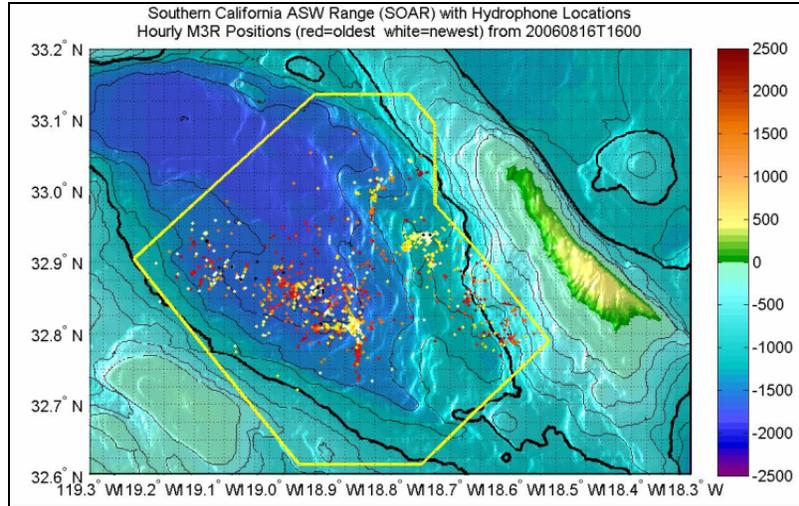
F.   SHR20060816T1700 JPEG (16 AUGUST 2006 1700 GMT)

Whale detections were still numerous on 16 August 2006 1700 GMT, but they were concentrated in the western section of SOAR.
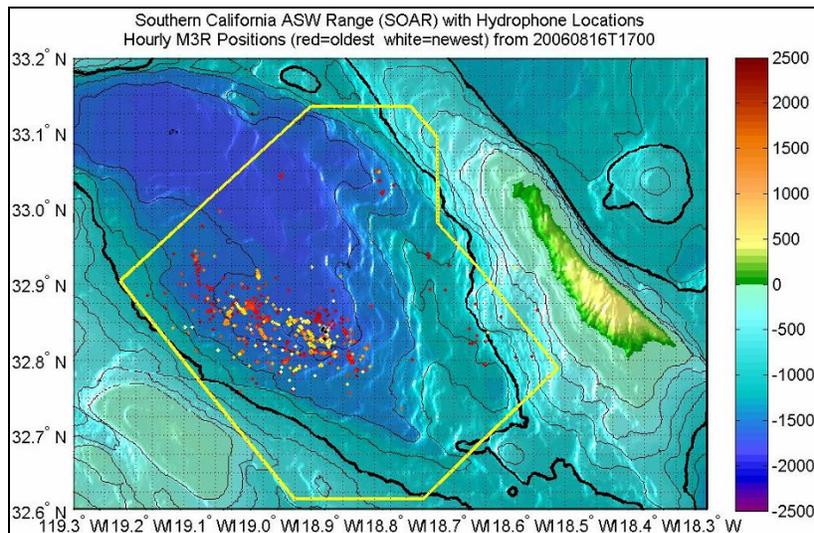
G. SHR20060816T1800 JPEG (16 AUGUST 2006 1800 GMT)

There were even fewer whale detections on 16 August 2006 1800 GMT.
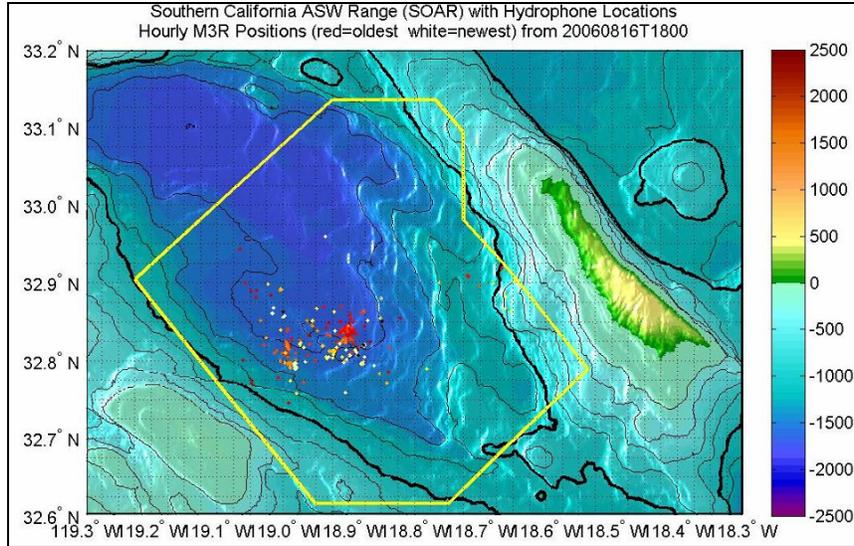
## H. SHR20060816T1900 JPEG (16 AUGUST 2006 1900 GMT)

Whale detections on 16 August 2006 1900 GMT were less compared to previous hours.
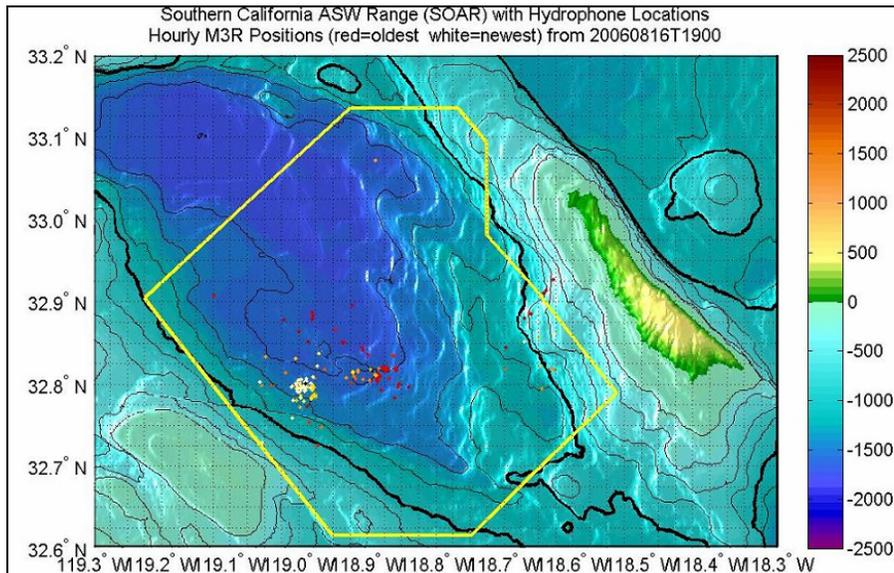
APPENDIX E. SCENES OF HOURLY FILES

A.   SHR20060814T1600 JPEG (14 AUGUST 2006 1600 GMT)

Whale detections were numerous along the northern border of SOAR on 14 August 2006 1600 GMT.
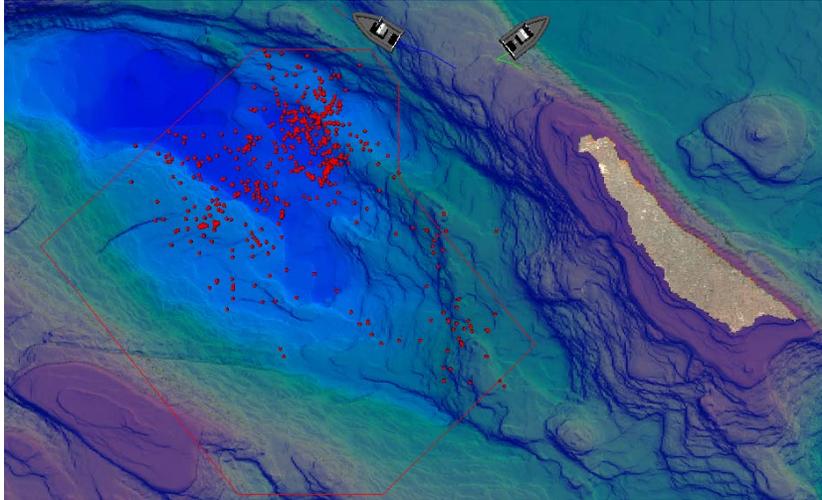
B.   SHR20060814T1700 JPEG (14 AUGUST 2006 1700 GMT)

The NUWC system was shut off on 14 August 2006 1700 GMT.
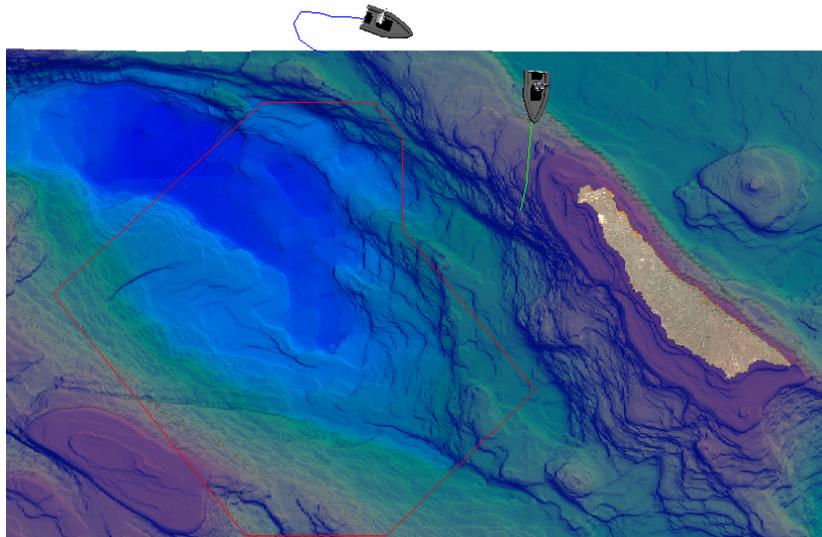
C.   SHR20060814T1800 JPEG (14 AUGUST 2006 1800 GMT)

The NUWC system remained shut off on 14 August 2006 1800 GMT.
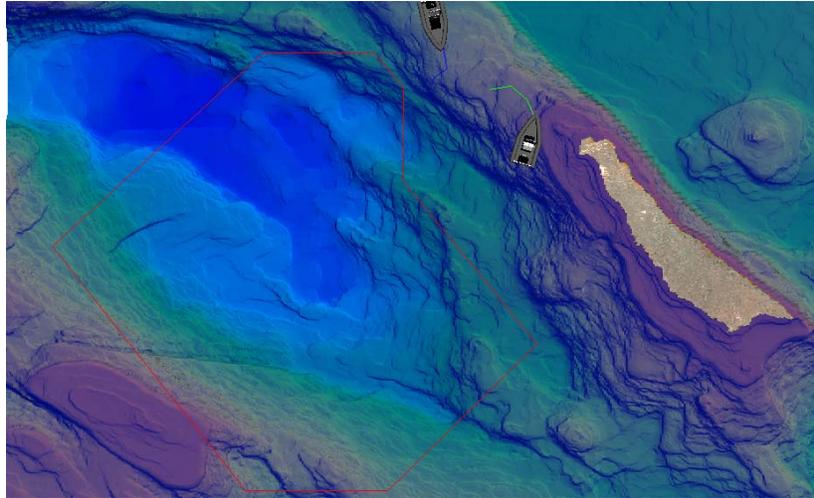
D.   SHR20060814T1900 JPEG (14 AUGUST 2006 1900 GMT)

The NUWC system was turned back on 14 August 2006 1800 GMT.
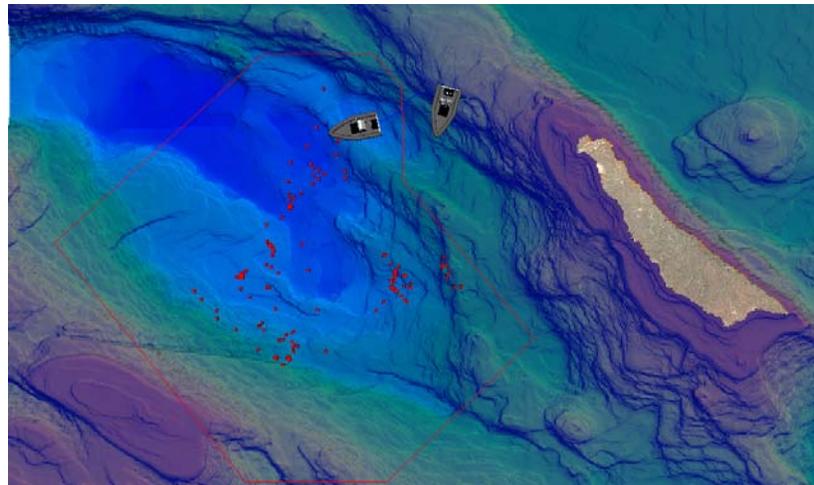
E.   SHR20060816T1600 JPEG (16 AUGUST 2006 1600 GMT)

There was one RHIB in SOAR when many whale detections were recorded on 16 August 2006 1600 GMT.
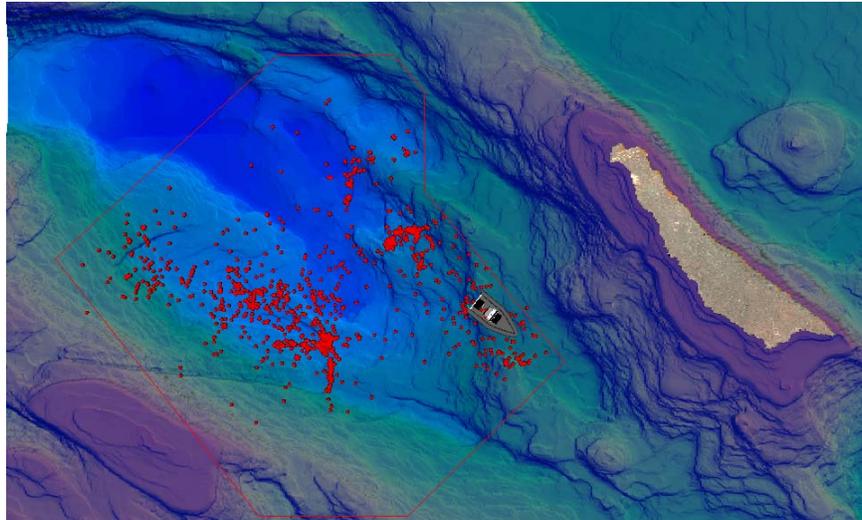
F.   SHR20060816T1700 JPEG (16 AUGUST 2006 1700 GMT)

Fewer whale detections were recorded on 16 August 2006 1700 GMT compared to the previous hour.
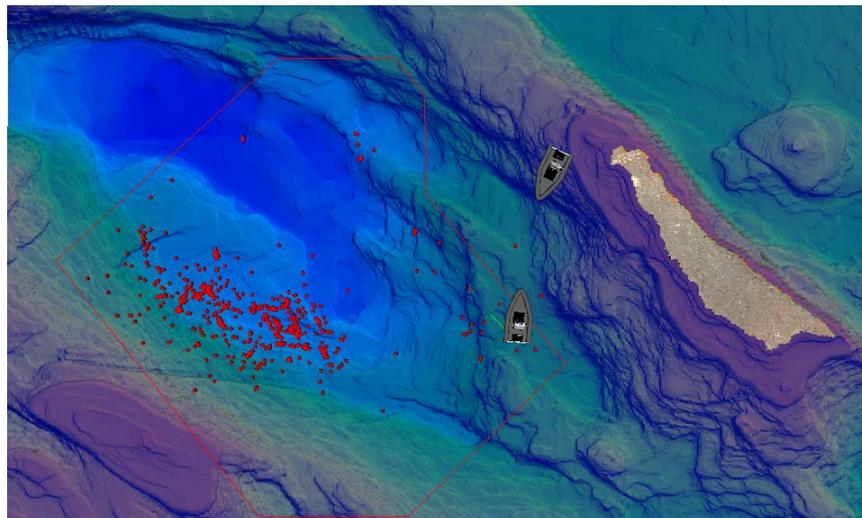
G.   SHR20060816T1800 JPEG (16 AUGUST 2006 1800 GMT)

As the second RHIB approached the SOAR border, less whale detections were recorded on 16 August 2006 1800 GMT.
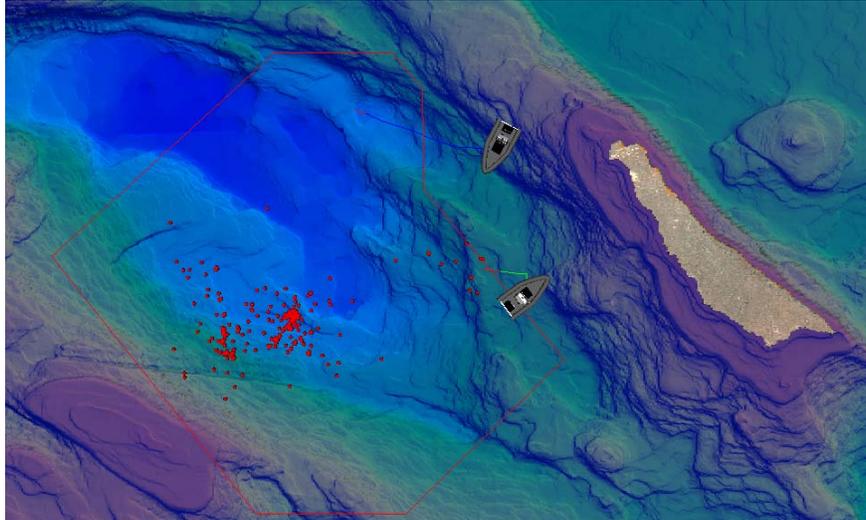
H.   SHR20060816T1900 JPEG (16 AUGUST 2006 1900 GMT)

With both RHIBs in SOAR, whale vocalizations were fewer on 16 August 2006 1900 GMT.
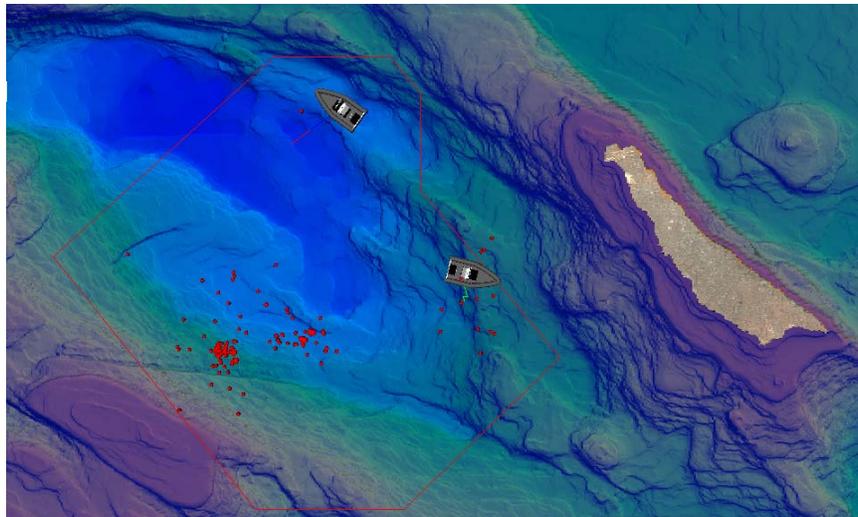
# APPENDIX F. NAVY IN THE NEWS CONCERNING MARINE MAMMALS

A.   INTRODUCTION

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B.   COASTAL COMMISSION RESTRICTIONS

The U.S. Navy sought recommendations by the California Coastal Commission on how to conduct training in marine mammal habitats. One of the guidelines included lowering sonar levels when whales are present.

Panel OKs Navy Sonar Limits
State Coastal Commission Seeks to Protect Marine Mammals
From MontereyHerald.com, 11 January 2007

The Coastal Commission voted Wednesday to impose restrictions on the Navy's use of sonar, which has been linked to harmful effects on whales and other marine mammals. The Navy has been using sonar during training exercises off the California coast for decades, although this is the first time it has come before the commission to seek approval of its activities.
The commission voted 8-1 to approve a staff recommendation placing restrictions on how the Navy conducts training, including moving exercises away from areas with a high concentration of marine mammals and lowering sonar levels when they are present. The Navy decided to seek the commission's consent because of new internal guidelines requiring it to ensure major exercises are environmentally compliant.
"We believe we've taken many steps to safeguard the environment, and we feel very confident the measures that we have in place protect the environment," said Matt Brown, spokesman for the Navy's southwest region.
The Secretary of the Navy will respond after reviewing the commission's recommendations.
Environmentalists applauded the commission's vote.
"The commission fulfilled its mandate from the people of California to protect our coast," said Cara Horowitz, an attorney for the Natural Resources Defense Council, which filed a federal lawsuit in Los Angeles demanding the Navy develop a mitigation plan for the exercises.

In July, a federal judge issued a temporary restraining order to block the Navy from using sonar during training in Hawaii. The NRDC, which sought the injunction, argued scientific evidence showed sonar can fatally harm marine mammals.

Both sides eventually settled, and the Navy agreed to stay away from certain sensitive marine habitats and increase whale monitoring in Hawaii. Since then, the Navy has said the steps were often unnecessary, hindered training, and in some cases weren't based on fact.

Mark Delaplaine, a Coastal Commission staff member, said commissioners were not convinced the Navy's steps go far enough and want the Navy to go beyond the standards established in Hawaii.

"We asked them to take a more precautionary approach," Delaplaine said.

The Navy conducts sonar-training runs in all its operational waters, including the East Coast, the Gulf Coast, Hawaii an the Pacific Northwest. Sonar or pulses of sound are used to track submerged objects- a key technology for finding enemy submarines.

Though many of the training exercises would take place up to 80 miles off California, the Coastal Commission maintains jurisdiction because the activities would potentially affect marine life within the coastal zone.

The Navy's sonar exercises have been responsible for at least six incidents of mass death and unusual behavior among whales in the past decade, a U.S. Congressional Research Service report found last year. Many of the beached or dead animals had damaged hearing organs.

In recent years, strandings have occurred in the Bahamas in 2000, the Canary Islands in 2004, and in North Carolina in 2005. Sonar is believed to affect other marine life, including fish reproductive rates and behavior of giant sea turtles.

C.   NAVY DISREGARDS COASTAL COMMISSION REPORT

Upon receiving the California Coastal Commission's new guidelines for restrictions on training along the California coast, the Navy decided not to comply and stated that it did not need the Commission's blessing to operate. Though not stated in this editorial, the Coastal Commission has since decided to sue the Navy over its use of sonar.

Navy's Sonar Stance a Show
From MontereyHerald.com, 15 February 2007

When the Navy asked the Coastal Commission to bless the use of high-powered sonar blasts during underwater war games, we were so impressed that we bestowed a Rave. Now, we must take it back and make it a Rant.

That's because the Navy's decision to send the matter to the Coastal Commission turns out to have been just for show, a PR job, a fake.

Originally, the Navy had said it was taking the plan to the Coastal Commission because of new internal guidelines requiring that major exercises meet environmental

requirements, state and federal. But after the commission approved the plans with a few conditions, the Navy decided the conditions were too confining and that it didn't really need the commission's blessing after all.

The federal Marine Mammal Protection Act "pre-empts state regulation," the Navy said unapologetically, seemingly forgetting that it had earlier sought and received a waiver from provisions of that law.

In advance of Southern California exercises that started Wednesday, a Navy spokesman said, "We can be responsible environmental stewards while our sonar operators receive the realistic training and experience at sea they need." In other words, butt out, California.

The exercises are important because they can help the military learn to detect quiet threats, such as nearly silent diesel submarines operated by North Korea. But the whales and dolphins that have died after similar operations in the Bahamas and elsewhere also important. Seeking the Coastal Commission's input was appropriate, and choosing to ignore it was not. Let the litigation begin.

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